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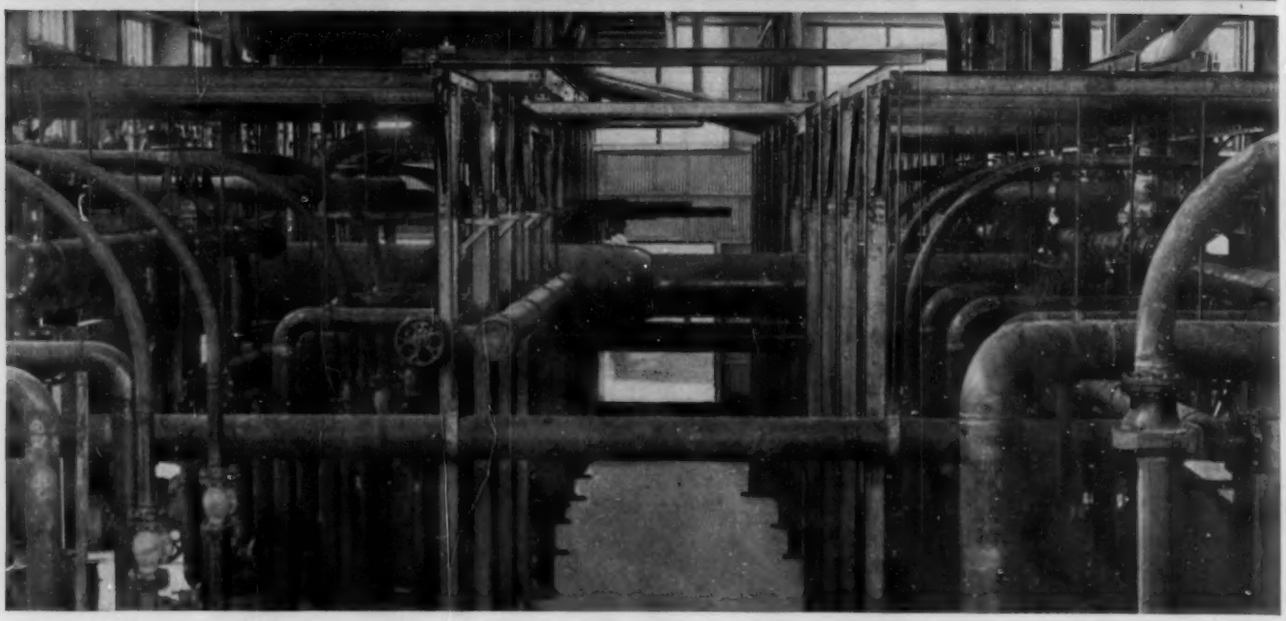

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THE
AMERICAN WELDING SOCIETY
JOURNAL

WM. SPRARAGEN, Editor | VOL. 13 | NO. 10

OCTOBER

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Some Welding Applications

A Pictorial Review

By A. F. DAVIS*

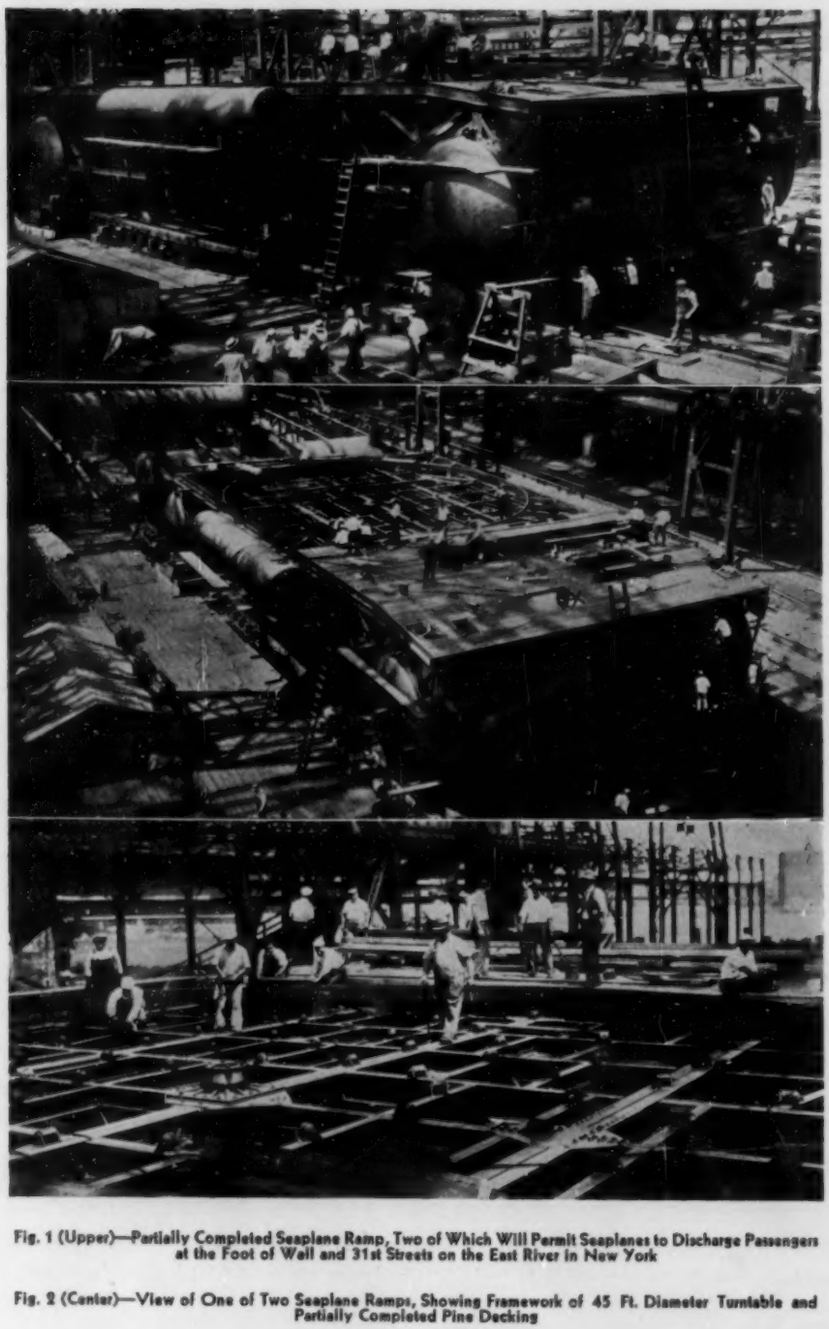

Fig. 1 (Upper)—Partially Completed Seaplane Ramp, Two of Which Will Permit Seaplanes to Discharge Passengers at the Foot of Wall and 31st Streets on the East River in New York

Fig. 2 (Center)—View of One of Two Seaplane Ramps, Showing Framework of 45 Ft. Diameter Turntable and Partially Completed Pine Decking

Fig. 3 (Lower)—The Small Rollers over Which the Turntable Revolves Are Arc Welded to the Five Sections of the Circular Top Steel Frame Shown in the Foreground

New Ramps Permit Direct Plane Service to Downtown New York

Direct water transportation to the business section of New York City for both privately and commercially owned planes is being provided by two floating seaplane ramps anchored in East River, one at the foot of Wall Street, the other at the foot of 31st Street. These ramps are of arc-welded construction and were built from designs furnished gratis by the United Dry Docks, Inc. and Edo Aircraft Corporation. The designs were requested by F. W. Selzer, commissioner of aviation of the city of New York. The ramps were built by the department of docks at the Brooklyn Navy Yard with material and labor paid for by the Temporary Emergency Relief Administration.

The two ramps are 89 ft. long by 56 ft. wide and weigh approximately 170 tons each. The structure of each ramp consists of two main steel buoyancy tanks which support five lanes of steel trusses covered with pine decking. Within the deck is a 45 ft. diameter power-driven turntable, the control mechanism of which is located in a small pit provided for the purpose.

The two buoyancy tanks are each 45 ft. long. The larger tank at the upper end of the ramp is 12 ft. in diameter; the smaller one at the lower end is 11 ft. in diameter. These tanks can be seen in Fig. 1. All the operating machinery is located in the larger tank. The smaller buoyancy tank is divided into four chambers or sections. The two end sections may be flooded or entirely emptied by means of two additional air chamber tanks shown at the side of the ramps in one of the illustrations.

The 45-ft. turntable, which moves the planes from the low or submerged area to the upper dry section, is driven by a 10-hp. hoisting engine. The circular channels under the framing of the turntable run over 100 rollers welded to the five sections of the circle of the top steel frame. Views of the turntable and rollers are shown in Figs. 2 and 3.

An air compressor driven by a 5-hp. motor furnishes the air to the two tanks, 20 ft. long by 5 ft. in diameter, which serve both as air receivers and buoyancy tanks. These can be seen just beneath

* Vice-President, The Lincoln Electric Company.

the circumference of the turntable in Fig. 2.

Each ramp contains approximately 6000 ft. of welding with a total of 7000 lb. of welding electrode used in each. The welding was done by the J. K. Welding Company, New York City, using 12 welding machines and 14,000 lb. of electrode.

In operation the seaplane lands on the submerged area of the turntable which is one-fourth under water. The ramp is then raised by pneumatic pressure from the two air chambers. This pressure is controlled automatically by mechanical control. The turntable is then revolved, carrying the plane to the dry upper area of the ramp.

New Type Diesel Engine Cylinders Built by Arc Welding

Blazing new trails in the construction of Diesel engines, F. B. Stearns, Cleveland, Ohio, is building an experimental Diesel embodying arc-welded cylinders for use in marine type engines.

Since both weight and space are at a premium, castings were discarded and arc-welded steel used for the cylinders and other parts. The cylinders illustrated are for a 320 hp. Diesel engine operating at 1300 r.p.m. (Fig. 4).

The design and arc welding of these cylinders was a difficult problem since some 16 pieces are required for each cylinder and the tolerance on the finished work was exceedingly small. The inner sleeve is of case-hardened steel and the outer portions of mild steel.

These are said to be the first arc-welded Diesel engine cylinders ever built.

Weight of Railroad Coach Reduced 35% by Arc-Welded Construction

Savings of 35% in weight are made possible by the use of arc welding in the construction of 52 new streamlined air-conditioned steel passenger coaches which the Chicago, Milwaukee, St. Paul and Pacific Railroad is building in its Milwaukee shops for both day and night service between Chicago and the Pacific Coast. The new construction of these coaches made possible through the use of arc welding will bring about new economies in train-operating costs and will facilitate higher speeds. In addition to the savings in operating costs, the company saves the price of thousands of pounds of steel in construction of each coach.

Of conventional sizes, the new Milwaukee arc-welded steel coaches are 80 ft. 8 in. long over the pulling faces of the couplers, 10 ft. wide and 13 ft. high above the rails. The total weight of the new coach is approximately 96,000 lb. as compared with 146,000 lb. for previously constructed coaches of the same size.

The new coaches are moderately streamlined and tubular in shape. The roof is of turtle-back form. There are none of the usual projections such as window sills, etc., on the sides of the coaches. Sheets forming the sides are rounded inwardly

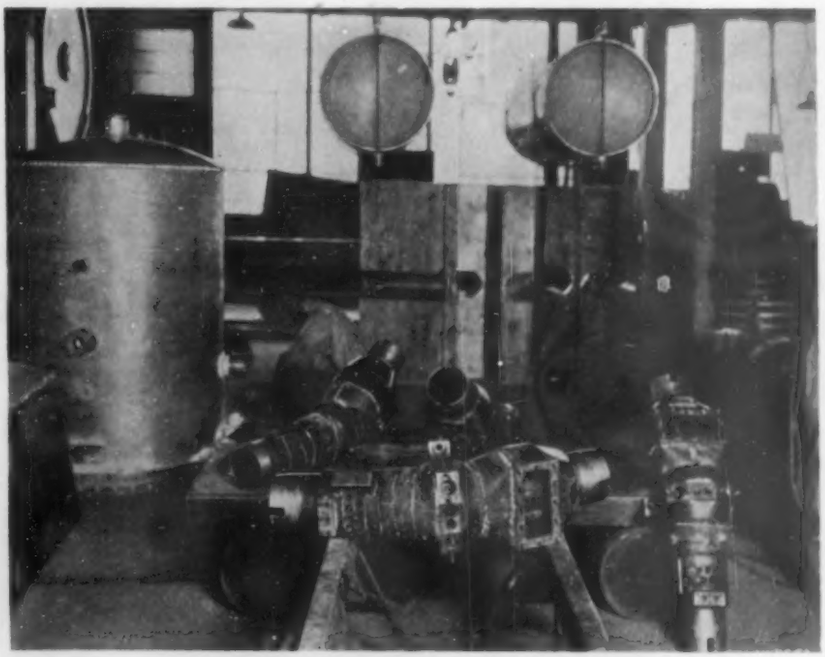

Fig. 4—Arc-Welded Cylinders Built for an Experimental Diesel Engine

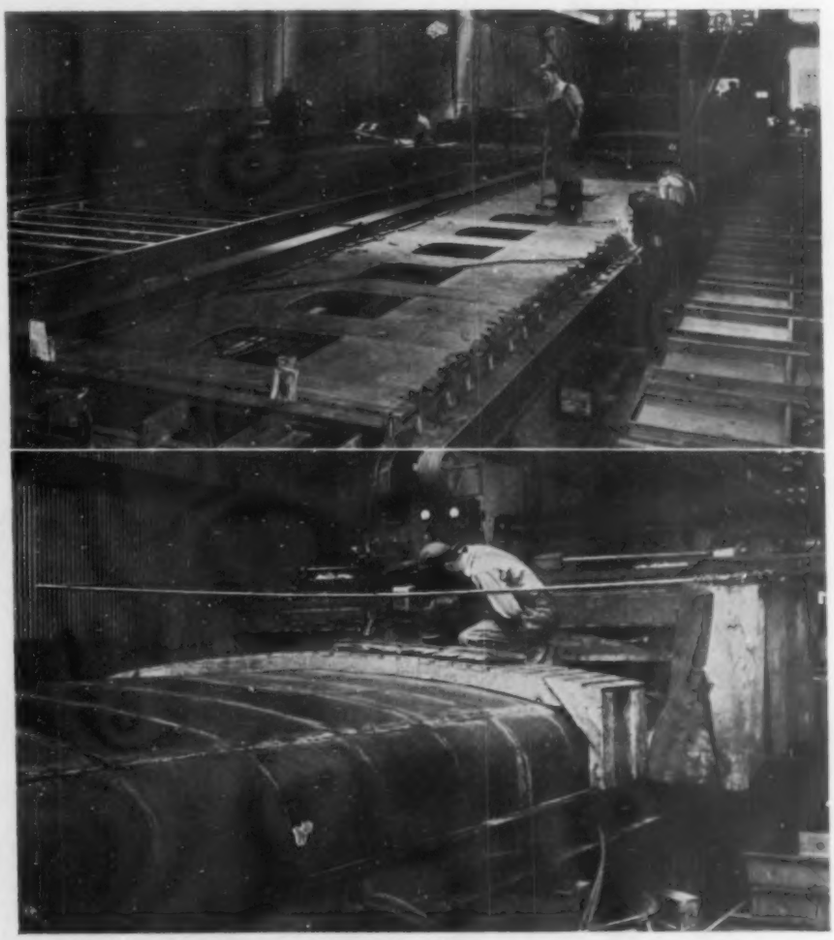

Fig. 5 (Center)—A Welder at Work on a Side of One of the New All-Welded Steel Passenger Coaches. A Total of 50 of These Is Being Built Throughout of Welded Steel

Fig. 6 (Lower)—Using a Lincoln Electronic Tornado Automatic Welder in Assembling the Sections in the Roof of One of the New All-Welded Steel Passenger Coaches Recently Placed in Service by the Chicago, Milwaukee, St. Paul and Pacific Railroad

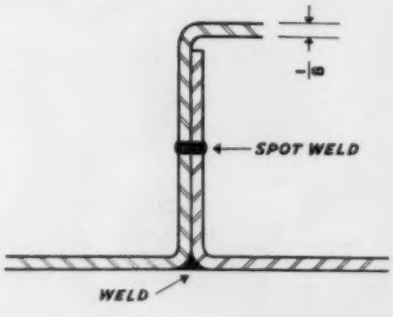

Fig. 7—Typical Automatic Weld Used in Fabrication of the Underframe

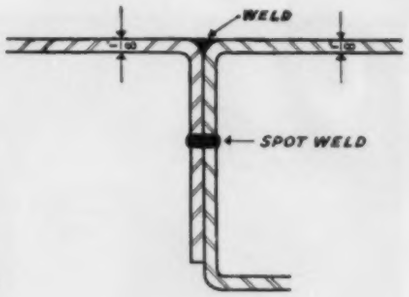

Fig. 8—Typical Automatic Weld Used in Joining the Pans Forming the Sides

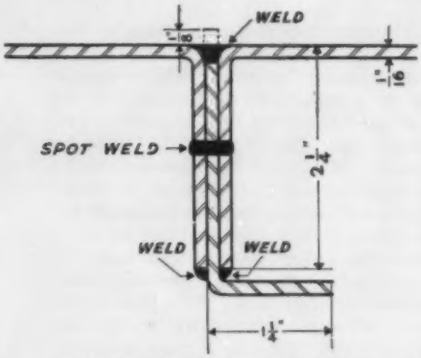

Fig. 9—Typical Welded Joint Used in Constructing the Turtle-Back Roof

below the windows to provide smooth passage of air along the sides of the coach.

The entire body of the coaches is built by arc welding. A built-up design consisting of structural shapes, plates and sheets joined by welding is the basis for construction of the underframe which includes the center sill, bolsters, buffer beams and body end sills.

In welding the pan-like sections of the floor structure of the cars, they are assembled together with flanges upward. The flanges are then spot welded, after which the entire assembly is turned over and welded continuously with the shielded carbon arc process.

A detail of this construction is illustrated in Fig. 7, which shows the under frame in its final position on the car, that is, with the continuous carbon arc automatic welds on the outside bottom or flush side.

The floor plans are of $^1/_4$-in. sheets formed with the flange extending from one side sill to the other. The welds joining this under frame floor structure to the center sills are intermittent.

Steel shapes, sheets and pressings all joined by welding are used in construction of the body and vestibule end frame. The side sills of the cars are 4-in., 8.2-lb. Z-sections extending from one corner post to the other.

The sides of the coaches consist of three different sizes of pans, all joined by welding. All side pans are fabricated from $^1/_4$-in. sheets. Structural strength is gained by forming flanges on sheets to give angle and channel effect.

The first sized pan used in side construction extends between the windows from the side sill to the side plate. The second size pan extends from each window down to the side sill. The top flange of these pans forms the window sill. The third sized pan extends from the top of the window to the side plate. These pans have angle-shaped flanges on all four sides.

Pressings used in the coach side construction are made with open corners (later filled in by welding) and with holes punched in the flanges for bolting them together and lining up the superstructure before welding.

The pans forming a side of a coach are assembled in a jig bolted down, welded automatically, one pan being welded to the other on the smooth outside face. These welds are continuous for the length of the pan.

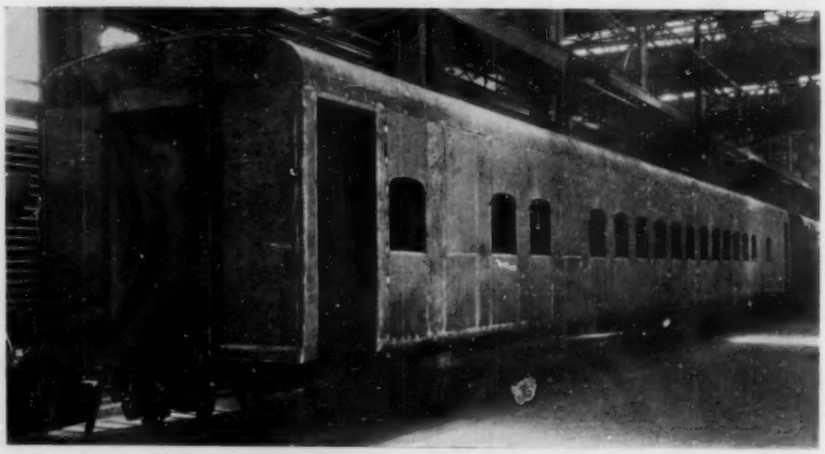

Fig. 10—One of 50 New All-Welded Steel Passenger Coaches Built by the Chicago, Milwaukee, St. Paul and Pacific Railroad. Savings of 50,000 Lb. in Weight and Considerable Cost Are Made Possible by Use of Arc Welding

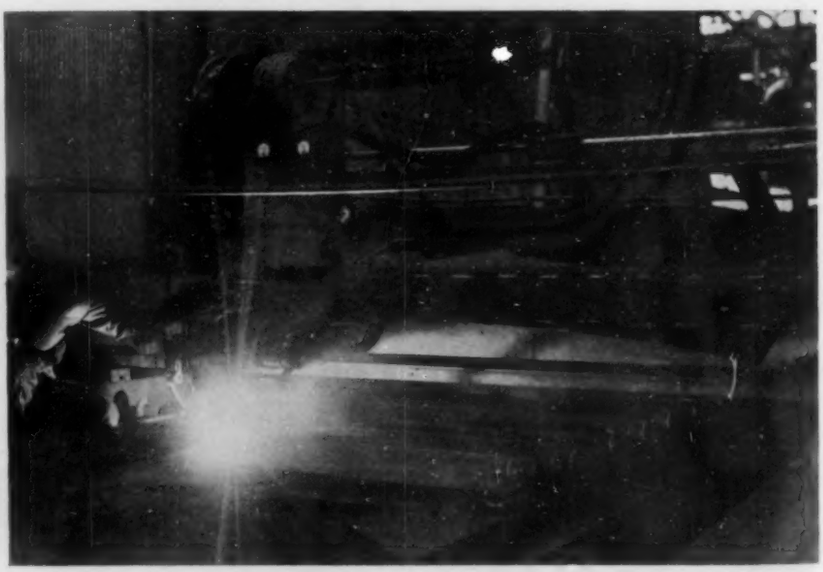

Fig. 11—A Carbon Arc Automatic Welder Being Used in the Construction of 50 Streamlined Air-Conditioned All-Welded Steel Passenger Coaches

The typical automatic weld used in side pans is shown in Fig. 8.

After the pan corners are filled in with a deposit of weld metal, and after the temporary bolts are removed, the side structure is turned over and the flanges are spot welded to one another.

In Fig. 5 can be seen one of the sides of a coach being welded manually at the flange ends.

The window frames are fabricated from 12-gage steel, pressed into U-shaped contours. Flanges project inwardly to coincide with the window construction.

Construction of the turtle-back roof consists of 1/16-in. steel sheets pressed into pans flanged on all four sides and also 3/16-in. pressed side plates. Steel strips 1/8 in. by 3 in. welded between the center pan flanges form the ridge pole.

In welding the roof pans, a strip projects above the surface of the pans and the carbon arc used in the automatic welding melts the strip down, thus providing filler metal between the flanges. The typical weld employed in construction of the roof is shown in Fig. 9. Automatic welding of the roof is shown in Fig. 6.

The smooth external appearance of the coach shown in Fig. 10 results from the smooth, even bead deposited by the automatic welding and by a system of water cooling which minimized warpage. This water cooling system consisted of an arrangement of drilled pipes in connection with the welding jig. Located under the material being welded, these pipes provided a continuous spray of cold water upon the under side of a joint while it was being welded. This method of cooling was sufficiently effective to permit placing the bare hand on the weld within 5 in. of the arc. Due to the fact that heat was prevented from penetrating into the flat surfaces of the pans, warping was reduced to a minimum.

No grinding was necessary in finishing the automatic welds. The manual welds were ground down as needed.

Every consideration was given to passenger comfort in working out the construction details of these modern, indeed luxurious, passenger coaches. There is a washroom at either end of each coach. Vestibules and steps are also improved to add to the passenger's ease in boarding and leaving the cars. Riding comfort is still further increased by a new type of heating and ventilating equipment, also by a new system of rigging for air brakes which reduces noise of operation.

In addition to all arc-welded construction, other notable features of these coaches include: four-wheel cast steel trucks with self-contained brakes and journals mounted in roller bearings; elimination of noise by use of rubber in trucks and other parts; installation of unusually wide plate glass windows; use of a special material sprayed over internal metal wall surfaces to deaden noise.

Fig. 12—This 30 Ft. Long Arc-Welded Barking Drum Doesn't Bark, But It Has Plenty of Bite. It Is Used to Remove Bark from Logs at a Papermaking Plant

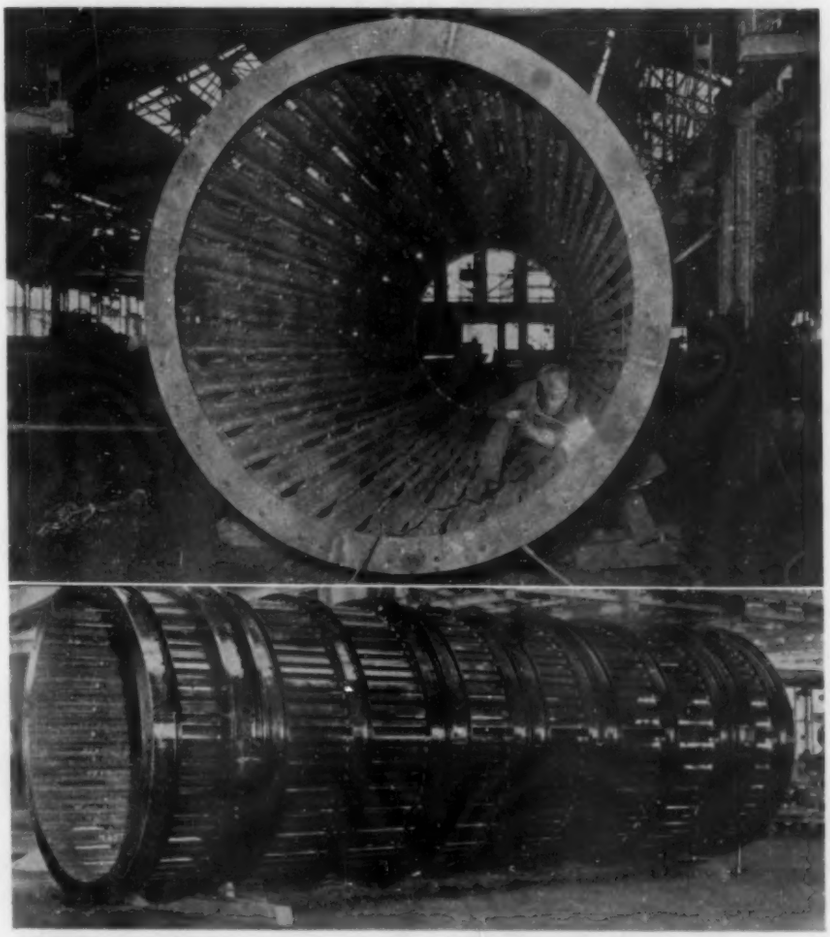

Fig. 13—Arc Welded into One Rigid Piece of Steel Frame Work, the Drum Must Withstand Severe Operating Conditions. The Rivets Shown Were Used Only to Fill Holes Punched for Fitting-Up Bolts

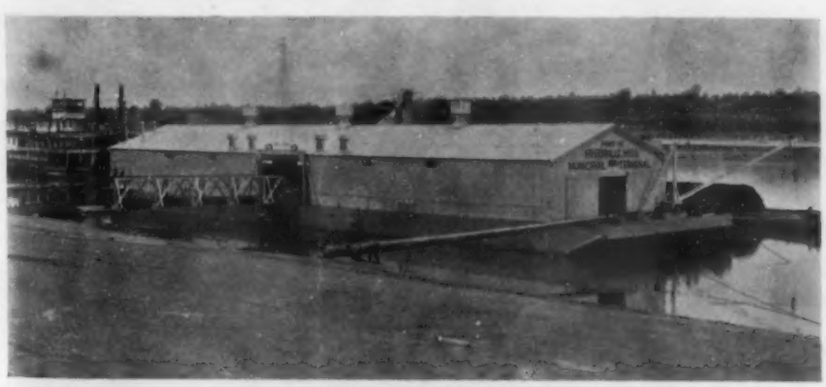

Fig. 14—A 230-Ft. Wharf Boat Built Entirely by Arc Welding for the City of Greenville, Miss., on the Mississippi River

Barking Drum Has Plenty of Bite

Unlike the proverbial barking dog, the barking drum illustrated really bites.

Short lengths of logs fed into the drum are stripped of their bark before being ground or chipped and cooked into pulp for making paper. (Figs. 12 and 13.)

The arc-welded drum pictured was built for the Nekooso Edwards Paper Company by Fibre Making Processes, Inc. It is 9 1/2 ft. in diameter and 30 ft. long, made up of a series of special rolled members or U-bars welded to the inside of ship channel rings. The rounded part of the bars, corresponding to the bottom of the U, protrude on the inside of the drums and tumble the wood as the drum revolves. The bark passes from the drum through the spaces between the U-bars.

The drum is suspended in a frame by means of chains which rotate it at a speed of 7 1/2 to 10 revolutions a minute. The wood is fed into one end and the bark is removed while passing through the drum.

The U-bars are welded to the circular channels, a 5/8-in. bead being used on each side of the bar. Sufficient holes were punched in the bars and channels to permit the drum to be bolted up during welding. The fitting-up bolts were removed as soon as the welding was completed and rivets driven to fill the holes.

The drum was welded by the shielded-arc process by The Chicago Bridge and Iron Works.

Arc welding was used to secure strength and rigidity and economy in fabrication.

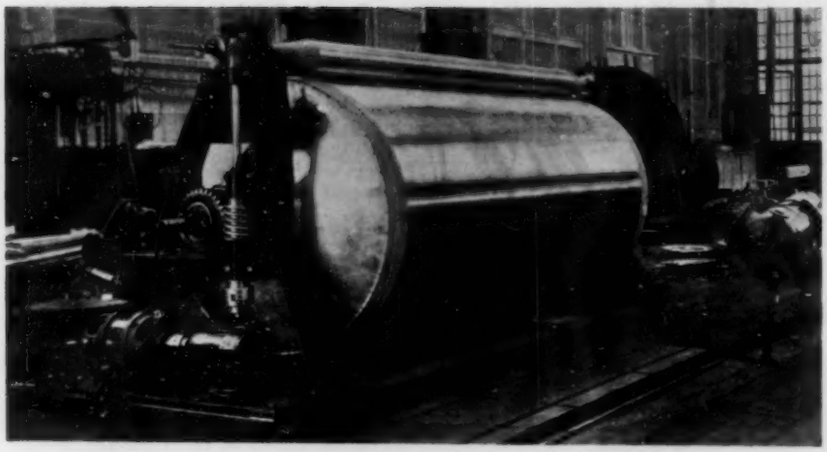

Fig. 15—Rotary Drum Dryer of Stainless Steel and Aluminum Built by Arc Welding

Arc Welding Aids Traffic on Ole Man River

Arc welding helped the city of Greenville, Miss., to have terminal facilities on the Mississippi River even in spite of the 50-ft. rise and fall in river levels and at great savings over other types of construction. On account of a 50-ft. variation in height of water during the year a stationary terminal could not be considered. In its place, a wharf boat which would adapt itself to the rise and fall of the river was built. The hull of this floating terminal is 230 ft. long and built on the transverse system entirely of steel arc welded. It was built in the shipyard of the Ingalls Iron Works at Chickasaw, Alabama, under specifications of the American Bureau of Shipping. Plans and specifications were prepared by V. M. Friede, naval architect of New Orleans, La. S. Lecourt, civil engineer, took care of the reinforcing of the levee and installation of dead men. (Fig. 14.)

Water-tight bulkheads divide the hull into eight holds. Two are used for water ballast, two for grain storage and one as a pump room. A total of 30 water-tight compartments, built by arc welding, greatly reduce the insurance premium.

The cargo house, 196 ft. long by 48 ft. wide by 14 ft. high, is located on deck. Eight sliding doors at 24-ft. centers give access to the house on the river side. A 24-ft. opening on the starboard side corresponds with the location of the bridge which connects with the shore. This bridge is 72 ft. long, 12 ft. wide and designed to carry a 16-ton load.

A 300-ft. travel of the bridge on the inclined levee is required by the 50-ft. rise and fall of the river. To permit this travel the shore end of the bridge is mounted on a truck which runs on rails. Horizontal and radial movements of the bridge are taken care of by a spherical universal joint and conical rollers.

A system of ballasting enables keeping the wharf boat and river barges on the same level for loading and unloading operations.

The pneumatic grain-handling machinery has a capacity of 1000 bushels per hour. It is operated by three dust-proof motors of 75, 10 and 2 hp. By means of by-passes and various hose, mounted on universal joints, grain can be discharged from river barges to the wharf boat, or directly into truck and sacks through weighing scales or from the wharf boat itself. The grain-handling equipment is sup-

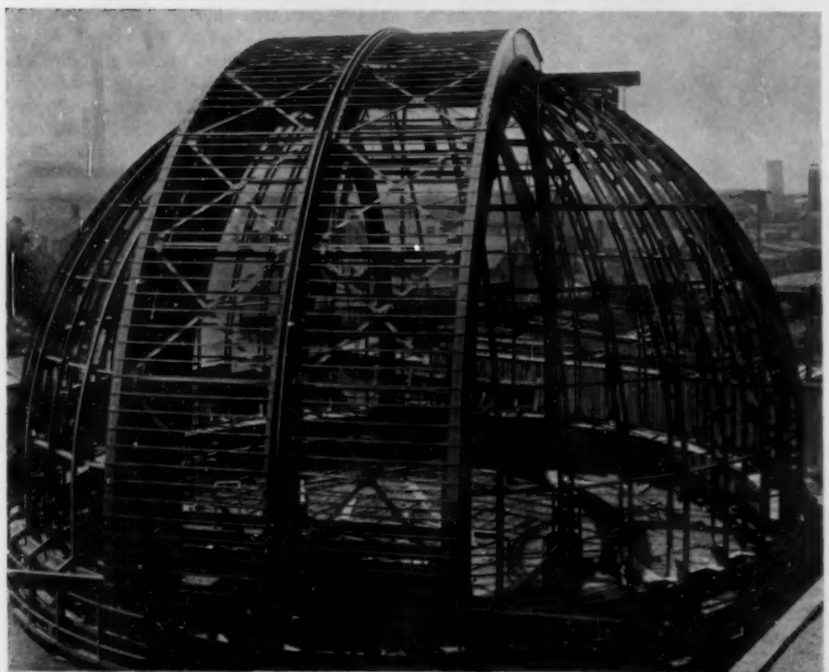

Fig. 16 (Center)—Looking Like a Gigantic Mouse Trap, but Built with the Precision of a Watch Maker, This Dome for the New McDonald Observatory Will Travel 1500 Miles from Cleveland to Its Permanent Home on Mt. Locke, Texas. Photographs Shown through Courtesy Warner & Swasey Co.

Fig. 17 (Lower)—Through This Aperture, Astronomers Will Study the Heavens Using the World's Second Largest Telescope. Arc Welding Played an Important Part in the Construction of the Dome

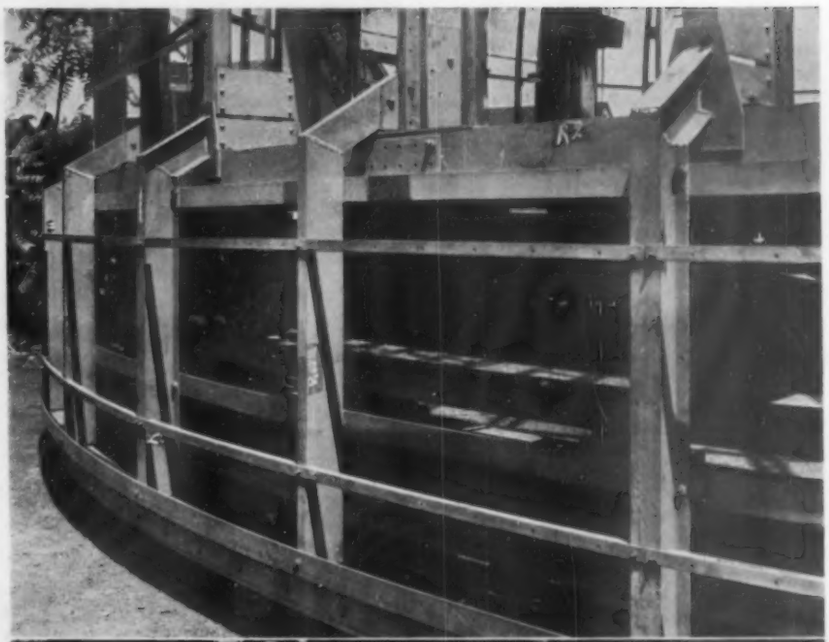

Fig. 18 (Top)—Typical Use of Arc Welding to Secure Strength and Rigidity in the New Observatory. The Earthquake Bracing for the Building Will Also Be Arc Welded. The Bolts Shown Are Merely for Temporary Assembly

ported on a structural steel foundation, independent of the cargo house. This arrangement eliminates the possibility of vibration.

The wharf boat is moored by four steel cables attached to two reinforced concrete dead men. Two 90-ft. spar poles breast the wharf pole from the shore.

Novel Steam Drum Dryer Built By Welding

An unusual rotary steam drum dryer built of arc-welded stainless steel and aluminum for a large food manufacturer has been completed by The Struthers Wells Company, Warren, Pennsylvania.

The dryer, illustrated in the accompanying Fig. 15, is 5 ft. in diam. and 10 ft. long. It is built to withstand 100 lb. working pressure. The heads are of high-carbon steel insulated and lagged with polished aluminum sheets. The surfaces of the stainless steel main shell and top roll were machined and polished within a tolerance of 0.005 in.

New Observatory to House World's Second Largest Telescope

Framework for a new observatory dome to house the world's second largest telescope started this month on a 1500-mile journey to the summit of Mt. Locke in southwestern Texas. The structure, fabricated and pre-assembled in Cleveland with arc welding playing an important part, will be re-assembled near Fort Davis, 40 miles from the nearest railroad.

There on the mountain peak the structure will be rooted to the earth, protected against earthquake shocks by arc-welded steel bracing. There astronomers of the University of Chicago and University of Texas, at an elevation of 7000 ft. will begin new explorations of the solar system.

Mt. Locke was chosen as the site of this new observatory because of unusually clear atmosphere with better observing conditions than perhaps any other location in the United States.

McDonald observatory, as it is to be called, was designed by the Warner and Swasey Company, Cleveland, Ohio, for the University of Texas. In it will be placed an 80-in. reflecting telescope 26 ft. in length.

Fig. 19 (Center)—The Steel-Melting Electric Arc Fused Together Hundreds of Parts Used in the New Observatory. This All-Welded Stairway Shown under Construction is a Typical Example

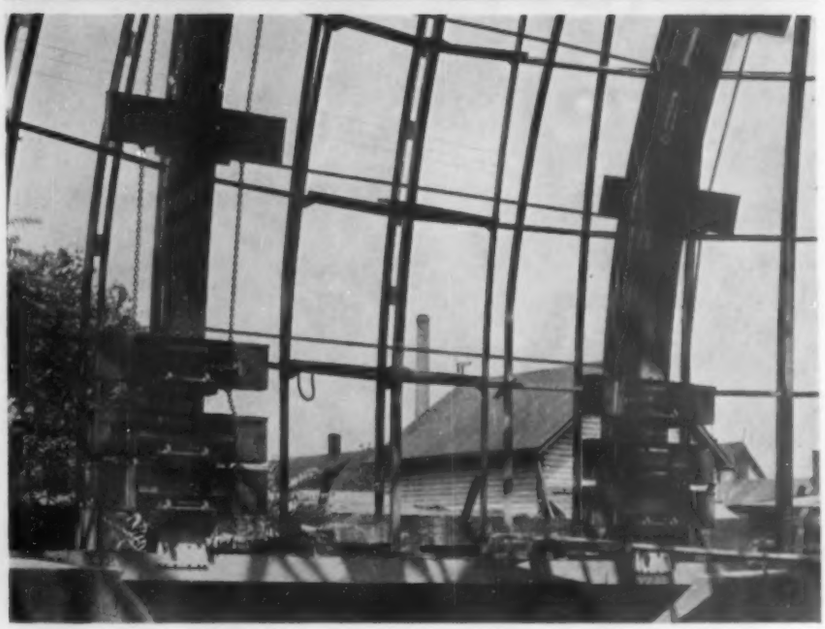

Fig. 20 (Bottom)—These Huge Counterweights, Connected by Heavy Chains, Were Fabricated by the Electric Arc Process. They Serve to Balance the Observing Platform of McDonald Observatory

The dome of the observatory has been erected in Cleveland by the Paterson-Leitch Company (see Fig. 16) under supervision of the Warner and Swasey Company, designers. The dome is 62 ft. in diam. with a height above the foundation of 73 ft. Construction of the dome required 125 tons of structural steel. An equal tonnage will be used in the sub-structure. After the building has been erected on Mt. Locke, it will be covered with about 25 tons of galvanized iron sheets.

Floors of the structure are of the "battle-deck" type, entirely arc welded for rigidity. The first floor of the supporting structure will be used for libraries and offices. The second floor will contain sleeping compartments, laboratories and photo developing rooms.

Two main girders and a base ring constitute the main structural members of the dome, which is mounted on a plate and girder base fastened to the top of the columns of the observatory building. The main girders are 4 ft. 6 in. deep with $^3/_8$-in. web plates, 8 x 6 x $^1/_2$-in. bottom chord angles and 6 x 6 x $^3/_8$-in. top chord angles. The semi-spherical contour of the dome is formed by the shaping of auxiliary ribs which are fastened to the main girders and base ring. These auxiliary members are alternately 3- and 4-in. channels and split beams. Skirting hangars are of welded construction and fastened to the auxiliary ribs. (Figs. 17, 18 and 19.)

Two 10-in. channels, reinforced by a 6-in. beam, form the bottom ring. These channels were joined with the flanges facing each other.

The supports for the conductor bars, brackets, as well as the shield which prevents dirt getting into electrical conductors, are all of arc-welded construction.

An open space 16 ft. wide between the main girders extends from the base of the dome to a point 9 ft. beyond the peak. This opening is covered by two movable shutters. Although the shutters weigh 16 tons they are so balanced that they are quic'ly and smoothly opened or closed by a 2-hp. motor. Four movements of the dome mechanism are provided by push button control within easy reach of the astronomer. The dome will revolve on 26 30-in. wheels running on tracks mounted on the top girders of the sub-structure. The dome-turning mechanism is cable driven by a 5-hp. motor.

Access to all parts of the dome and telescope is provided by an arc-welded electrically moved observing bridge running from the base to the top of the dome. This bridge is self-leveling. Arc-welded counter weights (see Fig. 20) insure smooth movement of the bridge. A stairway built as an integral part of the dome gives access from the observer's floor to the bridge. Adjustable pulpits extend from the bridge and permit further adjustments of the telescope.

The two semi-circular elevating platforms, arc welded on either side of the telescope pier, can be raised hydraulically 15 ft. above the observing floor. These platforms make it possible for the staff to make observations at lower points of the telescope tube.

Uniform temperature, necessary for greatest accuracy of observation, is assured by circulation of air between the inner and outer sheathing of the dome and sub-structure. Air enters at the foundation and passes up through louvres at the top of the dome.

To provide maximum protection against earth tremors, the earthquake bracing is to be entirely arc welded.

Welding of the structural work, trucks, counterweights, observing platform, stairways, doors and window frames, railings, flooring, earthquake bracings and other welded parts is done by the shielded-arc process.

Welding will also be employed in the construction of the 26-ft. telescope tube. Arc welding is said to surpass all other means of reducing deflection or sag in telescope tube construction. The construction of this new tube will be similar to that used in Perkins Observatory, Ohio Wesleyan University, at present the third largest telescope in existence.

Construction of the dome and sub-structure of McDonald Observatory began January 15th and will probably be completed during the late fall.

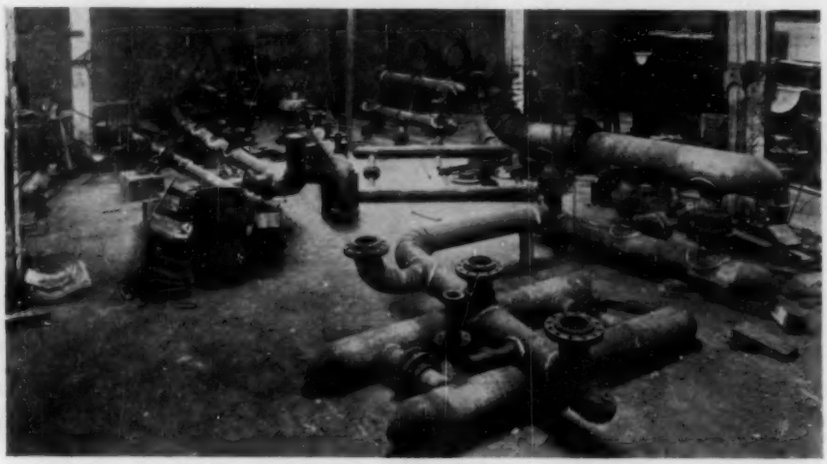

Fig. 21—Arc-Welded Manifold Assemblies for the New Washington, D. C., Underground Steam Distribution System

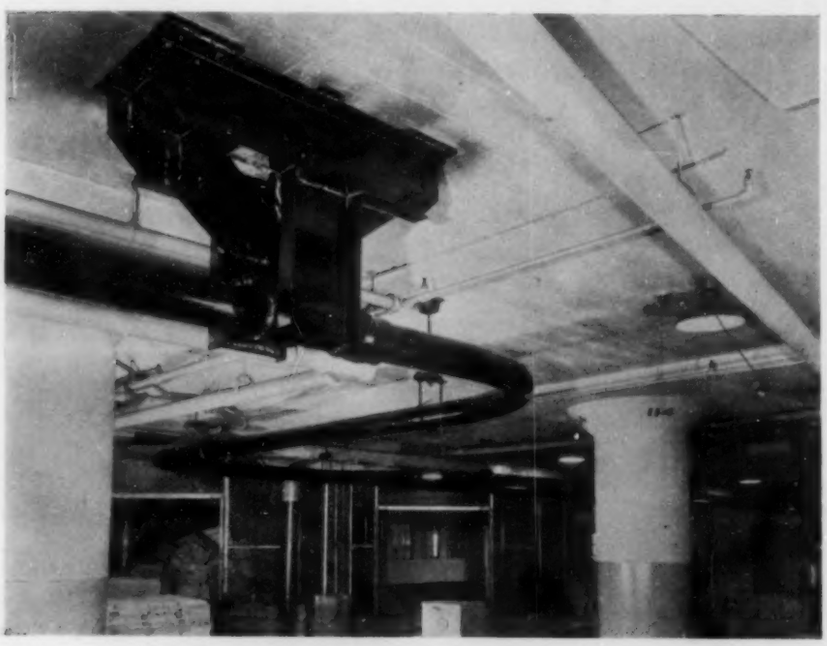

Fig. 22—General View of 6-in. Arc-Welded Main in Federal Warehouse

Million Dollar Steam Line Arc Welded for Federal Government

Forty-two thousand, eight hundred feet of underground arc-welded steam lines now supply heat for U. S. Government buildings in Washington, D. C.

This gigantic piping system cost more than $1,250,000. The contract was awarded by the Treasury Department to

the Northeastern Piping and Construction Corporation, North Tonawanda, New York.

Most of the federal buildings in Washington, including the White House, are now heated by steam from a district heating system. (Figs. 21 to 23.)

The district served by the new system is bounded by Sixth Street, N. W., E. Street, N. W., Twelfth Street, N .W. and C Street, S. W. It serves the following buildings: Commerce, Post Office, Justice, Treasury, Labor and I.C.C., Smithsonian and other museums, Agriculture, Printing, Court House, Patent Office and others.

The new line illustrated in the photographs is designed for 300-lb. working pressure. High pressure steam mains range from 18 in. down to 4 in., while condensate, return and drip mains range from 10 in. to $1^1/_4$ in. Specifications called for 246 slip type and packless expansion joints, numerous expansion loops, steam flow meters and much intricate piping work.

All the pipe joints and sleeves, necessary structural steel work, guides, anchorages, etc., were arc welded.

The Northeastern Company is the construction subsidiary of the American District Steam Company, originators of District Heating Systems which supply steam for heating and power purposes from a central boiler plant.

Fig. 23—Tunnel to New National Museum, Showing 8-in. and 4-in. Steam Lines

*Discussion of "Alternating-Current Arc-Welding Transformer and Circuit Characteristics"** by A. M. Candy†

[Printed in September 1934 issue of this Journal.]

By H. A. WINNE‡

BECAUSE of the present intense interest in alternating-current arc welding Mr. Candy's excellent paper is very timely. The curves which Mr. Candy shows representing the variation in arc current with open-circuit voltage are correct, but I am inclined to question somewhat his conclusion that the open-circuit voltage of the transformer and reactor combination should be on the order of 110 volts, when using heavily coated electrodes.

Examination of the characteristic curves of a representative direct-current welding generator shows that if we are holding any given current with a 40-volt arc, and then lengthen the arc out to 50 volts, the current will drop to approximately 80% of the value at 40 volts. If the arc is short circuited the current will rise to about 180% of the value at 40 volts. On the other hand, from the curves which Mr. Candy shows it is apparent that with the A.C. transformer-reactor combination with 75-volt open circuit, the current with a 50-volt arc is 87.5% of that of a 40-volt arc, and the current with the arc short circuited is only 117% of the 40-volt current. Of course, the reactance of the D.C. welding generator circuit will reduce the momentary fluctuations to values below those calculated from the characteristic curves, but examination of an oscillogram on a D.C. welder operating at 25 volts shows that the momentary short-circuit current is approximately 150% of normal, as compared to the maximum possible 117% on the A.C. equipment with 75 volts open circuit.

Experience in our factories has demonstrated that with proper electrodes it is thoroughly practical to weld with an open-circuit voltage as low as 75, and I think that the trend in open-circuit voltage of A.C. equipments is going to be gradually downward from the present usual values of 100–110 volts. A lower voltage is of advantage to the user in that it improves the operating power factor of the equipment, and lessens what slight hazard there might be in using 100 volts, or so. With an open-circuit voltage of 75, there is very little excuse for installing the automatic voltage reducing equipment which is now sometimes used, with its attendant complication and expense. I know of at least one foreign country in which the maximum open-circuit voltage of welding equipments is limited by law to 75 volts, and still a great deal of A.C. welding is successfully done with equipments having no higher than 75 volts open circuit.

* Presented at Fall Meeting, A. W. S., New York, October 1–5, 1934.
† Welding Engineer, Westinghouse Electric and Manufacturing Co.
‡ Industrial Engr. Dept., General Electric Co.

Historical Developments and Future Possibilities of Welding*

By D. S. JACOBUS†

THE art of fusion welding has advanced rapidly since the Boiler Code Committee of the American Society of Mechanical Engineers published Rules for Fusion Welding of Drums or Shells of Power Boilers in 1931, which rules were followed in the same year by its revised Rules for Fusion Welding of Unfired Pressure Vessels. The AMERICAN WELDING SOCIETY cooperated with the Boiler Code Committee in preparing these rules and continues to cooperate on all matters bearing on welding.

The formulation of rules to cover fusion welding was a long drawn out process. In March 1920 the Council of the American Society of Mechanical Engineers requested the AMERICAN WELDING SOCIETY and the American Society of Refrigerating Engineers to appoint committees to cooperate with the Boiler Code Committee in the preparation of rules covering fusion welding, with the idea of incorporating these in the Boiler Code.

The question might be asked why the AMERICAN WELDING SOCIETY did not prepare rules independently of the Boiler Code Committee. The answer is a simple one, namely, that the Boiler Code had been legally adopted by a number of States and Municipalities and those in charge of its enforcement had jurisdiction over boilers and pressure vessels. Any welding rules relating to boilers or pressure vessels would, therefore, have to be passed on by the State or Municipal authorities in charge of the enforcement of the Boiler Code, and as these authorities cooperate closely with the work of the Boiler Code Committee, the logical avenue of approach was through the Boiler Code Committee.

A public hearing was held by the Boiler Code Committee on December 5, 1921 at which a tentative Code was reviewed. At this meeting there were many different opinions expressed, some claiming that their welding processes were the best and the only ones that could be safely used. Realizing the need for further data before the formulating of rules, the American Bureau of Welding called a meeting on April 28, 1922 for the purpose of organizing the manufacturers of welded vessels to deal cooperatively with the situation. The report of the tests made at the Bureau of Standards was published in the May 1923 issue of the JOURNAL OF THE AMERICAN WELDING SOCIETY and was a most useful contribution. There, however, remained radical differences of opinion between the various interests, and the Boiler Code Committee failed in its effort at that time to secure a general agreement.

The first A. S. M. E. Boiler Code was published in 1914. This Code sanctioned the use of fusion welding, then called autogenous welding, only where the stress or load was carried by other construction which conformed to the requirements of the Code, and where the safety of the construction was not dependent upon the strength of the weld. From this time on the Committee was urged to adopt more liberal rules, and it held a number of public hearings on the subject. The Committee took the stand that it would adopt more liberal rules provided they were such as to insure safety, and asked for suggestions. As already stated, no feasible suggestions were forthcoming and there was a wide variation of opinion as to what the rules should be.

The Committee was criticized by many interested in welding, including prominent members of the AMERICAN WELDING SOCIETY, for its conservative attitude, and it many times reiterated its statement that it would be glad to sanction more liberal rules provided they would insure safety. It finally became necessary for the Boiler Code Committee to prepare a set of rules for fusion welded unfired pressure vessels in order to check accidents which were occurring through the bursting of such vessels. Such a Code was issued in 1927 without the approval of the AMERICAN WELDING SOCIETY. The maximum unit stress allowed, based on the thickness of the shell, was 5600 lb. per sq. in., and the use of fusion welding was limited to the following vessels:

(*a*) Air vessels, when the diameter does not exceed 20 in., the length does not exceed 3 times the diameter and the working pressure does not exceed 100 lb. per sq. in.

(*b*) Other vessels, under these rules, in which the circumferential joints only may be welded, when the inside diameter does not exceed 48 in., or 72 in., when at least 75 per cent of the load on a flat head is supported by tubes or stays.

It is interesting to note that in the 1927 issue of the Unfired Pressure Vessel Code both the term "Autogenous Welding" and the term "Fusion Welding" are used. The term fusion welding was first used by the Boiler Code Committee in a program which listed certain matters for discussion which was prepared for one of the numerous hearings. In this program the Thompson

* Presented at Los Angeles, San Francisco and Portland Sections, A. W. S.

† President AMERICAN WELDING SOCIETY and Chief Engineer, The Babcock & Wilcox Company.

process of electric-resistance welding was referred to as a process of electric-fusion welding. After the hearing some of those interested in what had been called autogenous welding proposed that its name be changed to fusion welding, and this was agreed to by the Boiler Code Committee.

After the issuance of the 1927 edition of the Unfired Pressure Vessel Code the Committee continued to be criticized by many interested in welding for its conservative attitude and it many times reiterated its statement that it would be glad to sanction more liberal rules provided they would insure safety. The welding interests failed to get together, however, and suggest any rules which were suitable for the purpose.

Those interested in welding in the State of California communicated with the American Society of Mechanical Engineers with the idea of inducing the Boiler Code Committee to allow higher stresses. After considerable discussion, during which a representative visited the Pacific coast, the Boiler Code Committee sanctioned a set of stresses which was used in the Air Pressure Tank Safety Orders issued by the State of California, effective January 1, 1928. The stress for butt-double-V longitudinal welds was 8000 lb. The stress for butt-single-V longitudinal welds for material of a thickness of less than $^1/_4$ in. was limited to 5600 lb. per sq. in. The stresses agreed to between the Boiler Code Committee and the State of California were embodied in the Unfired Pressure Vessel Code in August 1930 and the limiting inside diameter for air vessels with longitudinal seams was raised from 20 to 60 in., and the pressure from 100 lb. per sq. in. to 200 lb. per sq. in.

The use of air tanks over a number of years constructed as specified in the California Orders and in the A. S. M. E. Unfired Pressure Vessel Code has shown that the low-stress values provide a safety element which was not foreseen, which is that the tanks will corrode through at local points and leak, and in this way fail without exploding. This is such an important safety element that it should be retained where air tanks are used under conditions which may lead to failures through corrosion.

The Boiler Code Committee was pressed harder and harder in the effort to obtain more liberal welding rules. In order to make its position plain it prepared a statement in 1928, which was approved by the Council of the A. S. M. E., saying that the Committee would be justified in publishing rules which would be generally applicable, even though they could be met only by a single manufacturer under some patented process, whereas it could not sanction the use of tanks made by any particular manufacturer to the exclusion of others except through a general rule of the sort. The statement emphasized the fact that any rule embodied in its Code should be such that it would eliminate unsafe tanks.

At about this time representatives of the AMERICAN WELDING SOCIETY arranged for a conference with the Executive Committee of the Boiler Code Committee. These representatives said that they had become convinced that the conservative attitude of the Boiler Code Committee had been warranted as most of the welding practiced at the time the rules were written was of a relatively brittle and uncertain nature. The use of more ductile and carefully controlled welding had resulted in far greater safety and it was proposed that from then on the AMERICAN WELDING SOCIETY cooperate with the Boiler Code Committee in the formulation of more liberal rules. This offer was gladly accepted and from that time to the present the AMERICAN WELDING SOCIETY has cooperated in the preparation of all welding rules.

One of the first undertakings was to recommend a series of tests to be made at the Bureau of Standards in Washington which, if met by fusion welded vessels, would convince the Boiler Code Committee that the welding could be used for such purposes as the drums of power boilers. The proposed tests included so-called breathing tests, where the vessels were subjected to intermittent pressures and other tests to demonstrate the integrity of the welds. After agreeing on the tests to be made it was found to be impossible to obtain the necessary subscriptions to defray the expense, and the project was therefore abandoned.

The Babcock & Wilcox Co. finally decided to make tests along the lines of those which had been proposed for the Bureau of Standards. These tests were conducted at Barberton, Ohio, under the direction of Professor H. F. Moore of the University of Illinois. A preliminary report of these tests was published in the *Iron Age* of September 5, 1929, and the complete results were presented at the semi-annual meeting of the A. S. M. E. in Detroit, Michigan, in June 1930. These tests demonstrated the dependability of properly made fusion welds and established the working stresses which could be safely used. Several non-destructive tests of the fusion welds were investigated and the X-ray found to be the best for the purpose.

The results of these tests and a copy of specifications for Electric Arc Welding of Pressure Vessels proposed by The Babcock & Wilcox Co. were transmitted to the Boiler Code Committee on September 17, 1929. On the basis of the test results and the proposed specifications and recommendations secured from a number of sources, and with the cooperation of the AMERICAN WELDING SOCIETY, the Boiler Code Committee published Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers in the March 1930 issue of *Mechanical Engineering* and shortly thereafter a complete revision of the fusion welding rules of the Unfired Pressure Vessel Code. In August 1930 the Bureau of Engineering of the Navy Department issued specifications for fusion welded drums, including the requirement that all main seams be X-rayed, and a number of steam and water drums for boilers for marine service were constructed under them for the U. S. Navy. This gave an impetus to the use of fusion welded boilers, and from that time on the use of fusion welding has advanced so rapidly that practically all boilers which are now constructed for high pressures and high-duty service are fusion welded.

The use of the X-ray examination in making non-destructive tests of welds was a turning point in the development of fusion welding as it caused the safety of the welds to be less dependent on the human element. Experience has shown that one of the greatest assets of the X-ray examination is in helping the manufacturer to develop a technique which will assure sound welds and in keeping the work in his shop up to a high standard.

It will be evident on considering this brief history of the development of the Rules for Fusion Welding given in the A. S. M. E. Boiler Code that many took part in assisting in the preparation of a set of rules. This required over ten years, during which the art of fusion welding was rapidly advancing. The Rules as they now stand are still incomplete as they cover only drums or shells of power boilers and certain specific constructions sanctioned by the Code. We should not lose sight of the fact that we still do not know everything about fusion welding and we should all work together in an endeavor to make the Rules more complete and inclusive.

The AMERICAN WELDING SOCIETY was requested by the Committee to Coordinate Marine Boiler Rules to prepare rules for fusion welding which would be particularly adaptable to marine service. The Committee to Coordinate Marine Boiler Rules was organized December 27, 1929 at the suggestion of the Hon. R. P. Lamont, then Secretary of Commerce, to harmonize the results of previous efforts toward the same end in order to serve as the basis of a revision of the Rules of the Steamboat Inspection Service and the American Bureau of Shipping.

On December 19, 1931 a Sub-Committee of the Committee on Welding in Marine Construction of the AMERICAN WELDING SOCIETY started the work of preparing a set of fusion welding rules for marine use which were based on those in the A. S. M. E. Power Boiler Code, and through the cooperation and a special action of the AMERICAN WELDING SOCIETY these rules were approved by its Board of Directors January 5, 1932. This was certainly a record for speed in the preparation and approval of important rules of the sort, haste being necessary in order that they might be available for inclusion in the First Report of the Committee. The Rules for Fusion Welding given in the Report of the Committee to Coordinate Marine Boiler Rules have been modified from those prepared by the AMERICAN WELDING SOCIETY in order to meet the requirements of the Steamboat Inspection Service and the Coordinating Committe believes them to be the best available for the purpose.

Another set of welding rules is embodied in the API-ASME Rules for the Design, Construction, Inspection and Repair of Unfired Pressure Vessels for Petroleum Liquids and Gases which are sponsored by the American Petroleum Institute and the American Society of Mechanical Engineers. The Joint API-ASME Committee was appointed in December 1931. The welding rules in this Code have been brought thoroughly up to date by making a study of all previous Codes and a large amount of operating data and results of scientific tests contributed by the petroleum industry.

The reason for outlining the development of the Rules for Fusion Welding of Boilers and Pressure Vessels is to show the possibility of what can be done by all of us cooperating in the future. In the early days when the various interests were fighting each other no progress could be made. It should be borne in mind that we have only started on our way in the perfection of fusion welding and its use, and if we all work together from now on we can obtain that goal more quickly and thereby benefit the profession at large. For example, the question of what vessels or structures should be stress-relieved after welding is still a controversial one and much is being done in the way of research to determine the stresses at and near the welds. Again, new materials, such as alloy steels, are being developed, many of which are being welded, whereas there are no rules to cover the greater part of such welding. Some of these alloy steels are used to resist corrosive conditions, such as those encountered in chemical works and the like and under conditions where their high unit strength at high temperatures and lack of excessive brittleness at low temperatures makes them suitable for conditions which could not be met with plain-carbon steel. The problem of lining vessels with corrosion-resisting metal is another one demanding attention. These are only a few of the problems confronting the welding engineer. We certainly, as already stated, have a lot to learn and it has been said that progress in fusion welding has not advanced over 25 per cent of what will ultimately be accomplished.

The only rules so far discussed are those bearing on the welding of boiler drums and unfired pressure vessels as covered by the A. S. M. E. Boiler and other Codes. These are not the only rules that have been and are being formulated and they cover only a small part of the work that is being done. Rules are needed in other fields, such as in bridge building and ship construction, the replacement of castings by welded plates, the welding of piping, gas cutting and many other developments. A great deal of work has already been done in preparing rules covering these fields and a proposed American Standard Code for Pressure Piping which includes welding rules will shortly be issued by the American Standards Association.

Trained designers and inspectors are needed as well as trained men to do the welding. The procedure in welding should be carefully worked out by those in charge and not left to those doing the welding. The ease with which repairs can be made opens up a broad field but unless the work is most carefully regulated accidents are bound to happen. There is a great need for standardizing the rules for tests to qualify operators of welding equipment and our Society is now working actively in an endeavor to formulate a set of such rules for universal use in which it needs all the help that can be given by its sections and membership.

We are all vitally interested in solving the problems now at hand. One way of doing this is by inducing those interested in welding to join the AMERICAN WELDING SOCIETY to coordinate effort and assist in the work of developing standards. It has often been said that one cannot obtain any more benefit from a society than he is willing to contribute, and if we all work in this spirit we will do much in advancing our profession. Many members of this Society will think that they have done their duty when they have paid their dues, but unless there were other members willing to give generously of their time and services in promoting the welfare of the Society, and therefore of the industry, the Society could not exist. On the other hand, the service which the Society can render to its members is dependent in a considerable degree upon its income, which in turn is dependent largely upon its membership.

There are undoubtedly many thousands of men seriously interested in welding throughout the industry in the United States who are not members of the AMERICAN WELDING SOCIETY. This is in part due to the fact that welding is utilized in so many industries that the other engineering societies cannot ignore it and frequently provide papers on this subject for the interest of their members. The AMERICAN WELDING SOCIETY was the first national welding society in the world and there is no doubt as to the very important part which it has played in the tremendous advance made in the welding art during the Society's existence of 15 years. On this account the industries of the country owe a large debt to our Society, which debt should be recognized in vastly increased membership.

Even with our present small membership and small income your Society has weathered the depression, is clear of debt and the envy of some of the older societies that are not in so fortunate a condition. This has only been possible by the strictest economy and the curtailment of activities which might well have been carried out.

Time does not permit the enumeration of the many committees that have served and are serving the Society in the preparation of Codes or the giving of an account of the very large volume of research work carried out under the auspices of the American Bureau of Welding. It should also be noted that practically no Society funds

have ever been employed for the conduct of this research work and that all Committee members, as well as Society officers, with the exception of the permanent staff, have never received any remuneration for their work, or even been paid for their traveling or other expenses.

With the normal and expected general improvement in business conditions, and with the cooperation of the present membership of the Society, its growth during the next year or two should be very large, but each member should remember that it is his Society and that he has a real responsibility in helping to advance this growth. We have a golden opportunity, let us embrace it and make our Society the World leader in everything that bears on welding.

EDITOR'S NOTE: Following this preliminary statement lantern slides were shown to illustrate the type of evidence presented to the Boiler Code Committee in the early days of fusion welding. These were followed by slides to show the characteristics of modern welding and examples of modern fusion welded constructions.

Qualifying Operators of Welding Equipment*

By E. D. DEBES†

FLUCTUATIONS in labor, I believe, are greater in the shipbuilding industry than in most other industries. To illustrate this take the case of the Fore River Plant. In 1930, 6000 men were employed; in 1932, only 1100; at the present time about 3200 men are employed which will be increased to about 5000 next spring. During the high point in 1930, 95 riveting gangs and 116 operators of welding equipment were employed; at the low of 1932 only one riveting gang and 16 operators were working.

When the two heavy cruisers and the four 1850-ton destroyers were contracted for in 1933 it was estimated that a total of 650,000 lb. of welding electrodes would be required and that the peak labor load would be about 200 operators. Due to the great amount of welding on these vessels a peak load of only 15 riveting gangs will be required, showing the radical change in conditions during the last few years.

In the past the plant has operated schools for the training of riveters and operators when the demand was greater than the supply and it was decided to re-open the welding school as soon as conditions warranted such a move. In the Summer and Fall of 1933 the number of operators was gradually increased by hiring men who had sufficient experience to pass the Navy Department's qualification tests. Some of these men had worked in shipyards but generally had experience with bare electrodes only, so they had to go through a short period of training with covered electrodes, which are now used exclusively, to enable them to pass the Navy Department tests. Some men without shipyard experience have been hired, but as a rule these men have little experience on overhead and vertical welding and have to go through a period of training before being able to pass the tests.

The Navy Department tests for operators require satisfactory welds to be made in all three positions under conditions simulating as nearly as possible actual working conditions.

The school is conducted by the foreman of the welding department.

In accepting applicants preference is given to men who have shipyard experience in other trades and especially to men who are working in the plant or have worked in the plant before.

As a preliminary stage, before entering the school, the applicant is required to spend some time after working hours doing welding under supervision until he demonstrates some manual talent toward the trade. This gives some assurance that an applicant starting in the school will successfully complete the course and the fact that he is willing to sacrifice his own time indicates his seriousness and eliminates curiosity seekers. It has been found that younger men generally acquire the "knack" of welding more rapidly than the older men.

Upon entering the school the pupil receives a small compensation for every hour worked. A complete set of tools is provided and the pupil is turned over to the instructor who is an experienced welder and a man who has the "knack" of teaching.

The course is carried out in accordance with a "Welding Manual" developed by the plant and which contains the following chapters.

1. Metallic Arc Welding, Fundamentals.
2. General Safety Precautions.
3. How to Run a Bead.
4. Handling the Arc.
5. Placing the Arc Accurately.
6. Filling Craters Smoothly.
7. Tee Joint, Flat.
8. Lap Joint, Flat.
9. Vee Butt, Flat.
10. Single Vee Butt, Flat.
11. Running Bead on Inclined Surface.
12. Running Bead on Vertical Surface.
13. Tee Joint, Vertical.
14. Vee Butt, Vertical.
15. Laying a Bead Overhead.
16. Tee Joint Overhead.
17. Single Vee Butt Overhead.
18. Horizontal Lap Joint.
19. Vertical Lap Joint.
20. Overhead Lap Joint.
21. Filling Holes.
22. Thin Plates, Flat.
23. Thin Plates, Vertical and Overhead.

The specimens, welded by the student, are examined by the instructor and broken in the presence of the student. The instructor then points out whatever defects are apparent and instructs the pupil how to avoid such defects.

As the pupil gains experience and understanding of the technique of welding several regular test specimens are made and pulled in the laboratory in his presence.

When in the opinion of the instructor the work of the pupil is satisfactory a standard test specimen is welded by the student in the presence of a Navy Department inspector. These specimens are machined and tested in accordance with the Navy requirements.

If the test is satisfactory the pupil is put to work on welding of a simple nature, generally, in the shops where flat welding is mostly used.

The student operators, of course, work under very close supervision and records are kept of their ability and progress.

About 200 hours of training are required to develop an operator sufficiently to pass the qualification tests.

The school has been operating very satisfactorily, 90 per cent of the enrolled students passing the tests.

* Paper presented at the Fall Meeting, A. W. S., October 1–5, 1934, New York.

† Bethlehem Shipbuilding Corporation, Ltd., Fore River Plant.

Acetylene Welding as Pertains to Track Maintenance*

By BLAIR BLOWERS†

MY SUBJECT this afternoon is the general one of acetylene welding, as related to track maintenance. In the time allotted to me, I shall endeavor to visualize briefly for you the practices and developments of the past few years.

Two general conditions have confronted maintenance engineers in the last decade: First, the vast increase in speed of trains and the changes in motor power handling them; second, the decrease in the amount of money for maintenance. These conditions have had to be met, and the mere laying off of forces, or curtailing repairs to some classes of facilities, have not solved the problem. More constructive measures were necessary and *have been*, and are being adopted as their worth becomes known.

There are *four* general directions in which action has been taken; first, the improvement in materials and their reclamation; second, improved methods of organization and supervision of labor to obtain greater output for the expenditure allowed; third, the adoption of labor-saving tools and machinery and the sponsoring of their development; and fourth, the budgeting of expenditures so that work in its proper sequence is possible and labor conditions stabilized as much as possible.

The *improvement* and *conservation* in material has been most marked in the major items of ties, rail and other track fixtures. Ties have offered a great opportunity, for we were the most wasteful nation in the world in our handling of timber, and large economies were made in this item, which was also probably the first attacked. Expenditures for ties in the United States on Class I railroads were in 1922, $111,209,617; in 1932, $45,579,324, and in ties applied $66,641,634 and $39,190,473, respectively. This was done by improving the quality, not by reducing sizes; and, *in general*, proper tie renewals are being made. Treated ties are used universally. These are generally purchased on the specification of the A. R. E. A., and their inspection in the field has become very rigid.

In the Maintenance of Way Dept. the money spent for rail is second only to that of ties. Using the year 1928 as an average year for the purchase of new rail, the railroads in the United States spent over $57,000,000 for this item. This expenditure *leads us* to the subject of economy in the prolonging of rail life.

In rail practices, there has been a considerable trend to improved sections. *More* and *more* railroads are giving up their individual rail sections and adopting those of the A. R. E. A., which generally mean better design. With this, there has been an increase in weight of rail and this year's purchases have been largely in 112-lb. and 131-lb. A. R. E. A. sections, and it is the consensus of opinion that this trend will continue. The use of carefully designed joints, high-tension bolts and good lock washers has assisted in prolonging the life of rail. However, we still have *joint batter*. This problem of joint batter is most important, and large expenditures are being made to prolong the life of rail by welding, which would otherwise be replaced. The question of rail batter at joints has been with us since the early days of the railroads.

The first all-iron rail used in this country was on the Camden-Amboy Railroad in 1848. This rail was 7 in. high and had a base of $4^{5}/_{8}$ in. It was thought at the time that the rail problem had been solved, as this was a distinct improvement over the iron top wooden rail then in use. It was soon found that all iron rail battered very badly at the ends and this, in turn, causes considerable shock and damage to rolling equipment, crude as it was at that time. In those pioneer days battered rail was removed. Today, with aid of the oxyacetylene welding torch, battered rail is being built up in the track without interruption to traffic.

Some maintenance engineers contend that they do not have battered rail ends and that with proper joint maintenance, rail batter is prevented. Without a doubt, good joint maintenance tends to retard rail batter, but it will not prevent it if there is any great volume of traffic over the rails. This is due to the fact that the concentrated load of the heavy motive power and loaded cars, transmitted to the rail through the small area of contact between the wheels and rail, sets up a stress in most cases greater than the elastic limit of the steel. This results in what is generally known as "cold flow of metal."

Along the top sides of the ball of the rail a bead is formed by this cold flow of metal. At the ends of the rail a lip is produced. Consequently, where the metal can push out over the end in addition to flowing to the sides, the ends of the rail will show a depression. When once this depression is started, and it occurs rapidly with new rail, the hammer blows, resulting from the wheels dropping into the depression, accelerate the rate of batter. Inadequate joint maintenance likewise greatly increases it.

When rail ends begin to batter, maintenance expense begins to increase. The battered ends cause excessive wear of the bolts and angle bars, shattered ties and rough-riding track. If this stage of batter is allowed to develop, large and unnecessary expense is incurred to keep the track in proper condition. To overcome this, the process of reconditioning rail ends, both by reforming and adding additional metal by the oxyacetylene welding process, was developed.

When the work was first started, the process was both crude and expensive in comparison to that of today, and not entirely satisfactory. Due to the improvement in the welding torches and analysis of the welding rod, proper work is now being done. At first, but one welder and assistant were used and only the joints in the poorest

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condition were welded. *Today*, large gangs are employed and the work is done out of face, with large economies in costs per finished joint. In most cases, this is done by men *especially trained* for this class of work. In the early days, it was not thought advisable to hammer or to disturb the surface of deposited metal to any great extent. *Today*, as the new metal is applied, it is worked to develop as *nearly as possible* the original contour of the rail head, after which it is usually ground with a portable gasoline-driven outfit to make a smooth surface. At the present time, on most railroads, it is *also* the practice to slot or bevel the rail ends, before the work is considered finished.

The practice of reforming and building up rail ends to secure better riding track and to prolong the serviceable life of rail with its resulting economies, was not undertaken to any great extent until the year 1917. The further development of the art, together with our increased knowledge of the work and the necessity for keeping rail renewals to a minimum, have increased the practice until now practically all railroads have adopted the method and are reconditioning increased mileage each year.

In reply to a questionnaire sent out by the A. R. E. A. Committee and answered by twenty-four of the leading railroads, it appears that the rebuilding of rail ends increases the life of main track rail in first position from 50 to 100%. Of the roads reporting for the year 1932, approximately 85% of the joints were built up by the oxyacetylene process. The reports from the different roads show wide variations of costs per joint: for oxyacetylene from $0.43 to $1.50; for electric arc from $0.86 to $2.10. The cost, of course, is dependent upon the amount of material applied, length of weld, density of traffic, efficiency of the organization and whether or not work is done out of face.

While the heat treatment of rail ends is a recent development in the application of the oxyacetylene process to rail maintenance, it has been in use sufficiently long to prove its effectiveness in preventing rail end batter. This is substantiated by the fact that several of the largest railway systems have accepted the method of heat treating rail ends as standard practice, and are now applying it to reconditioned rail ends, as well as new rail.

In heat treating rail ends, the pearlitic structure of the steel is changed to the tougher and harder sorbitic. This is accomplished by heating the ends of the rail quickly and uniformly to a temperature of 1500 deg. F and then quenching with water to a temperature of approximately 300 deg. F. The metal is then reheated to a drawing temperature of 650 deg. F. and allowed to air-cool. It has been found that a final Brinell hardness of from 350 to 375 is best. If made harder, rails are apt to check and pieces break out.

The operator soon becomes very proficient in determining the quenching temperature by the color of the rail end. Too much should not be left to the eye, however. A pyrometer should be used to determine the quenching and drawing temperature, especially until the operator has had considerable experience and is sure his judgment is correct. Even then, the pyrometer should be used freely as a check. The drawing temperature is easily checked by striking a piece of 50–50 solder across the rail end. If the solder melts freely and oxidizes slightly in a few seconds, causing it to become straw colored, sufficient heat has been applied. If the solder remains bright, more heat is required. The drawing temperature can be checked by placing the points of the pyrometer in the molten solder. A suitable sprinkling can for quenching may be made by punching small holes in a pail or can. In order to secure best results, a given amount of water is used for each joint and is deposited in a given time limit.

Other items which involve large expenditures in track maintenance are frogs and switches. Before the advent of oxyacetylene welding, when these became badly worn, the only thing to do was to scrap them or replace worn parts. Today, when a frog or switch becomes worn, the worn part is built up and in many cases the serviceable life has been extended 100%.

Much of the building up of frogs and switches can be done without removal from track. At points where traffic interruptions are frequent, it is *advisable* and more economical to remove them and do the *necessary welding outside*, replacing them in the track, either in their former location or at some other point.

At the time frogs or switch points are welded, all bolts should be tightened and other work done, in order that they will be in the best possible condition. If this is carried out and proper attention given in the track, in many cases the frogs and switches can be welded several times.

On many roads, the heat treating of frogs and switches is done in conjunction with the building up of the worn part, and remarkable results have been obtained. In some cases, their life has been two and three times as long as new untreated parts in the same location.

The oxyacetylene welding in the Maintenance of Way Department of railroads has made great economies possible in many other classes of work. By the application of hard surfacing material to reface tie tamper tools, portable track upon which mole ballasting cleaning machines run, teeth of ditching buckets, and to earth-spreading blades, greatly increased life is obtained. Bronze and cast-iron rods are used for repairs to water lines, water cranes and other castings, failures of which formerly meant entire replacement.

One of the greatest essentials in automatic signalling and train control is proper electrical track circuits. If the track bonding is not good, signal failures will occur, often resulting in train delays and excessive battery consumption.

Until a few years ago, the wire pin-connected bond was used exclusively for track bonding; now the fusion type is *rapidly replacing* the former. The welded bond is shorter than that previously used, consequently it gives greater protection. The old style which extended outside the limits of the angle bars, made it possible for a rail to be broken anywhere within the joint bars without showing a danger indication. With the modern bond, applied to the head, at the very ends of the rail, practically *complete protection*, in case of broken rails, is afforded.

The electrical resistance of a fusion bond is a great deal less than the common wire bond. From this, it can readily be seen by the use of the more modern type battery consumption is materially reduced, and in some cases an annual saving of as much as $90.00 per mile of track is made.

Fusion bonds, properly applied, fail but rarely, whereas numerous failures of the old type occur. *Because of this*, less inspection of track circuits is required.

Much credit is due the companies interested in the acetylene industry and their representatives. The *development* of equipment and active cooperation by them, has resulted in our having competent and efficient operators. Furthermore, new and varied uses for our torches are being continually developed, and the economies speak for themselves.

Impact Resistance of Some Steels and Welds at Sub-Zero Temperatures*

By R. K. HOPKINS†

Introduction

A CONSIDERABLE amount of work has been done by various investigators over the past several years to determine the effect of low temperatures on the impact resistance of carbon and alloy steels as well as non-ferrous metals.

Practically all of this work, however, has been done on specimens which have been either quenched and drawn, or normalized and drawn. In one instance tests were run on specimens which had been annealed and drawn and annealed only.

No work of any note has been reported covering impact tests of fusion welds at sub-zero temperatures. Since this type of welding has been so universally accepted by industry, it naturally becomes important to know the mechanical characteristics of the weld at its operating temperature. A great deal of work has been done in this connection at high temperature, but little, if any, for temperatures below zero F.

In some cases, very large vessels and intricate piping systems are required to operate at low temperatures. In some of these systems, shock is not an unheard-of thing, and it therefore becomes necessary to design such plants for this condition.

Perhaps the most important point in the design of a plant which is to operate at low temperature is the choice of the material of which it is to be built. The next most important point is the heat treatment the various parts of the plant are to receive either before or after, or before and after fabrication.

Some plants, such as de-waxing plants, require very large vessels and extensive piping systems. Because of the large size of the units, it is impractical to quench and draw them after fabrication, but unfortunately the only available literature on the subject of low-temperature properties of metals indicates that they be either quenched and drawn, normalized and drawn, or annealed and drawn, in order to insure toughness. It is also impractical, because of the size of the units, to either normalize and draw, or anneal and draw.

As the necessity for a de-waxing plant had already arisen, and as the literature indicated a more or less hopeless situation, it was decided to attack the problem from another angle. Before starting work, however, the two following points were definitely decided upon:

1. That the plant be absolutely safe to operate at −40° F.
2. That, if possible, the cost be kept within commercial limitations.

PART 1

Scope

It was felt, after a thorough consideration of the literature, that it might be possible to put at least one type of metal in an acceptable condition for low-temperature service by giving it an extended draw at from 1100 to 1200° F., or it might even be possible to find a metal which would be acceptable after the regular stress-relieving heat treatment which, incidentally, is carried on at the above temperatures for a relatively short length of time.

With this point in mind, it was decided to test steel and weld metal on six types of commercial steels. Four samples of each steel were to be welded together, and each sample given a heat treatment at the above temperature for a different length of time. The following times were adopted: 2 hours, 6 hours, 12 hours and 36 hours.

After the heat treatment, the samples were to be tested in the following way:

1. Tension Test of all-weld metal.
2. Tension Test of plate material.

The above tests to be run at atmospheric temperature. (The literature conclusively showed that tensile strength and yield point increased, and elongation and reduction of area decreased as the temperature was lowered. It was therefore decided to run only the impact tests at the reduced temperatures.)

Brinell hardness determinations were to be made of the plate material, weld metal and plate adjacent the weld in the "heat-affected area." These tests to be run at atmospheric temperature before and after the samples were subjected to the low temperatures.

An analysis of each type of steel and of each weld was to be made for the following elements: Carbon, Manganese, Phosphorus, Sulphur, Silicon, Nickel, Vanadium, Chromium and Molybdenum.

The history of each plate was to be determined, such as: Maker, Heat Number, Slab Number, Type of Furnace, Finishing Temperature, Heat Treatment, if any, and Direction of Rolling.

The history of each weld was to be kept, such as: Size of Weldrod, Type of Steel in Weldrod, Kind of Coating, Volts and Amperes, Hand or Automatic, Welder's Number and his report as to the welding conditions.

A micrographic study was to be made of the plate, the weld metal and the plate adjacent the weld, with the idea of correlating impact results with grain size, if possible.

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Charpy impact tests were to be run in duplicate on the plate, the weld and the plate adjacent the weld, at room temperature, at −25° F. and at −50° F. If a suitable plate material and a satisfactory weld were found from the above tests, it was proposed that a full-sized pressure vessel be fabricated on a normal production basis, to determine whether or not the findings of this investigation could be put into commercial use. After this vessel was completely fabricated, it was to be cut up and tested so that the physical properties of each part could be determined.

Materials Investigated

The six commercial steels selected for tests were as follows: carbon-molybdenum, carbon-silicon, plain low carbon, 2¼% nickel, 3½% nickel and carbon-vanadium.

As a check on the accuracy of our equipment and procedure, a small piece of manganese-vanadium steel in the annealed and drawn condition was obtained from an outside manufacturer who had determined the impact resistance at atmospheric and sub-zero temperatures. The details of our check tests on this steel will be explained later.

Each steel was given a symbol as listed in Table 1 below.

Table 1

Symbol		Steel
M	=	Carbon-Molybdenum
S	=	Carbon-Silicon
C	=	Plain Carbon—Max. 10% C
N	=	2¼% Nickel
NH	=	3½% Nickel
V	=	Carbon-Vanadium
Z	=	Manganese-Vanadium

Identification.—Due to the large number of specimens to be tested and to their small size, a numbering system was devised so that each piece could be fully identified.

The first number (whether of one or two digits) in the symbol indicates the number of hours the specimen has been heat-treated at 1200° F. The letter immediately following this number indicates the type of steel, such as 6N, which means it is 2¼% nickel steel and has been heat-treated for 6 hrs.

The tension test specimens of plate and weld are distinguished from each other by the letter P or W following the letter denoting the type of steel, such as 6NP or 6NW.

In the case of the Charpy specimens, the number (whether of one or two digits) following the letter denoting the type of steel establishes the location of the keyhole notch. Odd numbers from 1 to 11, inclusive, indicate the keyhole notch is in the weld metal, such as 6N1 or 6N9, etc. Even numbers from 2 to 12, inclusive, indicate that the keyhole notch is in the "heat-affected area" adjacent the weld, such as 6N2 or 6N10, etc. All numbers from 13 to 18, inclusive, indicate that the keyhole notch is placed in the plate material well away from the weld, such as 6N13 . . . 6N16, etc. The last digit of the symbol indicates the temperature at which the bar was broken, where

7 = 70° F.
2 = −25° F.
5 = −50° F.

Such as..... 6N37	36C25	12M142
which indicate the following:		
Heat-treatment time at 1200° F.	6 Hrs.	36 Hrs.	12 Hrs.
Type of steel	2¼% Nickel	Low Carbon	Molybdenum
Location of keyhole notch	Weld	Adjacent to Weld	Plate
Temperature of test, ° F.	+70	−50	−25

In the case of the Z bars, the marking was slightly different, where

Z7	indicates	+70° F.
Z2	"	− 2° F.
Z5	"	−50° F.
Z8	"	−85° F.

The −2° F. and −85° F. temperatures were used to compare with results obtained by the outside concern who furnished the Z steel.

Where extra specimens were taken to check questionable results, an "X" appears in the symbol, such as 6N3X7.

Test Procedure

All welds were made between two plates 9 in. x 18 in. with the weld extending along the 18-in. edge. The plates were cut from the original plate so that the direction of rolling was parallel to the 9-in. dimension or, in other words, at right angles to the weld. This was done to simulate the conditions most generally met in the shop where the length of a plate is rolled into the circumference of a section. As it was impossible at the time to obtain rolled plates of the vanadium and the 3½% nickel steels, these were obtained as forgings 6 in. x 18 in. x 1 in. They were welded together with the direction of forging parallel to the weld.

Eight 9-in. x 18-in. plates were cut from each type of steel to make four welded samples, each of which received a heat treatment at 1200° F. for 2-hr., 6-hr., 12-hr. or 36-hr. periods.

After welding, each plate and weld was drilled for analysis and then acetylene cut as shown in Fig. 1. Each piece was plainly stenciled on the side representing the top of the weld. This method of numbering was adhered to throughout the test.

Tables 2 and 3 give the history of plates and welds respectively:

The slabs from which the impact specimens were to be taken were machined to ½ in. thickness and laid out as shown in Fig. 2.

Table 2—Plate History

Symbol	Plate Thickness	Maker	Heat No.	Slab No.	Type of Furnace	Fin. Temp.	Heat Treatment
M	2 in.	Midvale	8-2255	B-818	Acid O.H.	Normal	None
S	1½ in.	Bethlehem	74C231	..	Basic O.H.	Normal	None
C	1¼ in.	Worth	E-2057	27	Basic O.H.	Normal	None
N	1 in.	Worth	A-3320	75	Basic O.H.	1400°	Buried in sand
NH	1 in.	Crucible	16739	..	Basic Elec. Fur.	1400°	None
V	1 in.	Crucible	39385	..	Basic Elec. Fur.	1400°	None
Z	1 in.	Midvale	SE-452	..	Electric Induction	Normal	Annealed and drawn

Table 3—Weld History

Symbol	Size of Weld Rod	Weld Rod Steel	Coating No.	Volts	Amps.	Welder's Comments
M	5/16 in. x 20 in.	EB Grade	746	40–42	450	Good
S	5/16 in. x 20 in.	EB Grade	721	40–42	450	Good
C	5/16 in. x 20 in.	EB Grade	721	40–42	450	Good
N	5/16 in. x 20 in.	EB Grade	761	40–42	450	Crack in first bead each plate, then good.
NH	5/16 in. x 20 in.	EB Grade	761	40–42	450	Good
V	5/16 in. x 20 in.	EB Grade	763	40–42	450	Good

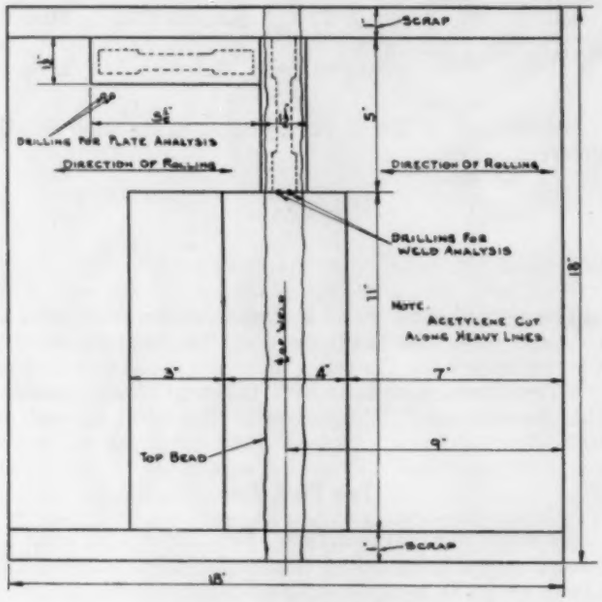


Fig. 1—Standard Welded Sample

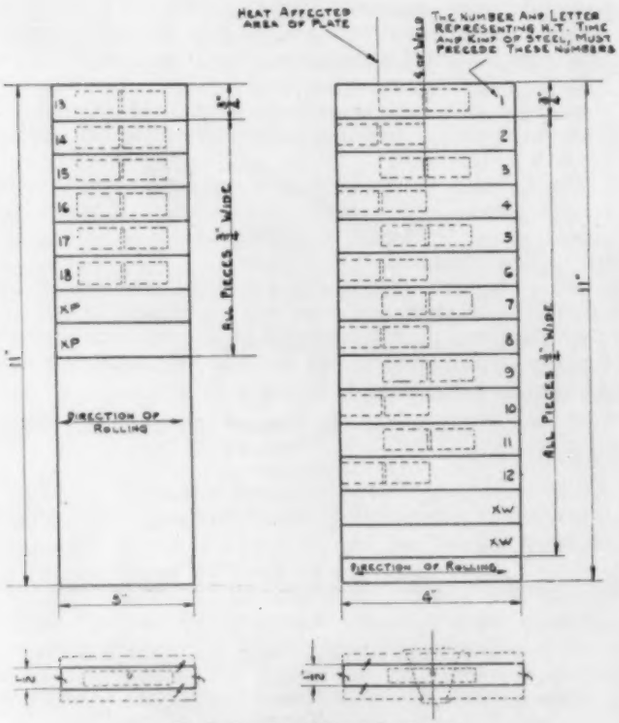

HEAT AFFECTED AREA OF PLATE
THE NUMBER AND LETTER REPRESENTING H.T. TIME AND KIND OF STEEL, MUST PRECEDE THESE NUMBERS
ALL PIECES 3/4" WIDE
DIRECTION OF ROLLING
5"
4"

Fig. 2—Location of Charpy Specimens

The slab containing the weld was then X-rayed so that the impact specimens containing the weld could be located in such a way that the area to be broken would not contain any defects. It might be stated that it was necessary in only a very few cases to take advantage of this facility.

The six odd-numbered bars representing the weld, the six even-numbered bars representing the adjacent area and the six bars representing the plate along with the extra bars, were then cut from the slabs.

All of the impact bars along with the 0.505-in. bars from each plate were then heat-treated for their respective lengths of time. In each case the pieces were furnace cooled.

On removal from the furnace, all tension bars were machined to the standard 0.505-in. x 2-in. dimensions. The impact bars were machined and finally ground to the dimensions shown in Fig. 3.

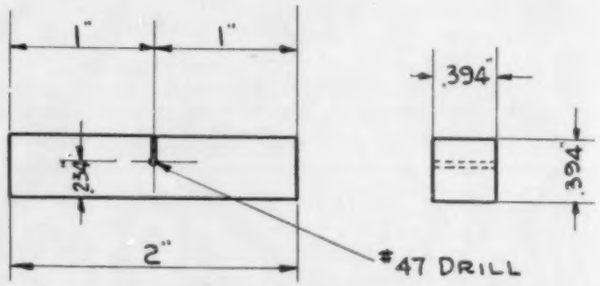


Fig. 3

It will be noted from this figure that, although the dimensions are A. S. S. T. Standard, the dimension locating the center of the drilled hole is shown as 0.234 in. from the bottom of the specimen, rather than 0.160 in. from the top as is customary. This was done to insure that the area of the section which was to be broken would remain constant. In this way any error in the height of the specimen would occur on the saw-cut side where it would be ineffective. It is felt that the standard sketches of Charpy bars should be changed accordingly. To further insure accuracy in the location of the hole, a drilling jig was built. Several specimens were drilled and then checked with a micrometer gage and found to be extremely accurate.

Tests

Tension.—All tension tests were carried out at atmospheric temperature on a Tinius-Olsen machine of 100,000-lb. capacity. The results obtained are given in Table 4.

Impact.—The impact tests were run on a 120 ft.-lb. capacity Amsler Charpy Impact machine. The machine was calibrated before the tests were begun.

As stated before, a special steel was obtained from an outside concern for check purposes. The results are given in Table 5.

As these results seem to be well within experimental accuracy, it was felt that the machine and technique were satisfactory.

TABLE IV

TENSILE PROPERTIES

SYMBOL	T.S.		Y.P.		El. 2"		R.A.	
	Plate	Weld	Plate	Weld	Plate	Weld	Plate	Weld
2M	60200	58500	35250	40600	35.5	35.0	60.1	59.4
6M	59750	60200	37550	45500	36.0	29.0	62.1	47.2
12M	60400	61060	34450	45500	35.0	34.0	62.3	58.8
36M	58250	58150	33000	41500	36.0	37.5	66.1	66.7
2S	61000	60000	31300	46500	36.0	36.0	63.0	67.3
6S	60000	60000	30000	44500	37.0	34.0	62.8	56.3
12S	62200	59300	30750	46650	36.0	32.5	59.8	57.0
36S	60750	58350	27850	44500	36.0	37.5	63.8	66.6
2C	45600	55400	24500	43500	44.5	35.0	75.4	63.8
6C	46950	54050	23400	40850	45.0	36.0	80.9	67.3
12C	47250	52800	24350	39150	43.0	21.0*	74.3	41.9
36C	44000	54750	21650	40000	45.0	34.0	79.0	64.7
2N	76500	93800	47400	89750	30.0	16.0	59.4	33.4
6N	76500	76700	47850	64150	30.0	23.5	57.3	48.6
12N	74400	83100	38650	72500	33.0	21.0	66.1	44.9
36N	73150	80400	35700	69400	30.5	24.0	66.1	55.7
2NS	77150	88000	48650	77150	29.5	21.0	58.6	56.2
6NS	84150	81900	50000	70300	28.5	25.0	56.0	56.3
12NS	87600	77400	48000	68800	25.0	24.0	50.0	50.3
36NS	92200	78250	51000	63000	20.5	23.5	40.7	49.2
2V	68000	84150	50000	46550	30.5	34.0	63.5	65.4
6V	66250	64500	45500	47250	30.0	34.0	59.8	66.8
12V	64500	63150	45800	45650	32.0	32.5	61.3	67.3
36V	63500	63750	46600	46700	34.0	36.0	68.0	67.9

*Bad area, bar taken too near end of weld.

Table 5—Charpy Ft.-Lb. Absorbed

	Temperature of Test, ° F.			
	+70	−2	−50	−85
Data from outside average of 2 check tests	63.3	58.3	..	46.0
	59.5	56.6	50.3	46.9

Since over 400 impact bars were to be broken, special care was taken to see that each was carefully marked and prepared. With the aid of a small jig and some cold etchant, the keyhole notches were placed accurately in their proper locations, such as in the weld, the adjacent area and in the plate.

All bars having a 7 as the last digit of the symbol, were tested at room temperature, which was approximately 70° F. The bars to be tested at −25° and −50° F. were placed in a well-insulated vessel containing acetone. The temperature of the acetone was lowered by the use of CO_2 ice. When the desired temperature was reached, it was held for one hour before the bars were removed for test. The temperature was maintained manually and was held to within plus or minus 4° F. The thermometer used was a Hiergesell immersion type, graduated to −60° F.

A determination of the rise in temperature of the test specimen from the time it was removed from the bath until it was broken was not made because several investigators had shown it to be negligible if the cycle did not require more than 10 to 12 seconds. A time study was made on several practice bars which indicated that an average of about 6 seconds was required to complete the cycle. During the actual test, no bar required over 9 seconds to be broken from the time of removal from the bath. In order to reduce the rise in temperature even further, the gage which is used to center the specimen in the machine was kept in a bath at the same temperature.

Table 6 gives complete data from Charpy impact tests.

Brinell.—The Brinell tests were carried out on a Tinius-Olsen machine with a 10-mm. ball and 4000-kg. capacity. The impressions were taken on the impact specimens at atmospheric temperature in the plate, in the weld and in the adjacent area, both before and after the specimens had been lowered to −50° F. The load used for test was 1500 kg.

TABLE VI

CHARPY FT.-LBS. ABSORBED

TYPE OF STEEL	+70° F.			-25° F.			-50° F.		
	Weld	Adj.Weld	Plate	Weld	Adj.Weld	Plate	Weld	Adj.Weld	Plate
Drawn for 2 Hrs.									
M	37.5	47.5	36.0	36.9	45.7	4.7	30.8	38.0	2.5
S	38.5	45.8	31.3	32.7	41.5	2.0	26.2	35.5	3.0
C	31.3	71.5	51.2	29.0	4.07	4.0	11.2	26.7	1.4
N	27.6	37.6	48.1	19.2	57.7	60.6	14.5	34.5	51.7
V	36.4	22.8	38.4	34.0	19.9	37.1	30.7	21.1	31.4
MN	34.6	44.6	32.9	23.5	41.2	34.4	18.4	39.6	28.5
Drawn for 6 Hrs.									
M	38.5	51.1	38.8	35.9	45.1	5.0	34.8	46.9	4.0
S	36.0	39.0	31.4	37.0	36.1	4.0	26.4	25.6	1.8
C	36.3	65.5	66.0	35.9	54.0	1.8	32.0	36.6	4.1
N	26.0	30.0	39.8	24.6	37.8	34.8	19.6	34.1	23.6
V	39.8	27.8	38.3	31.6	28.5	36.4	30.6	21.3	30.0
MN	34.8	34.5	40.5	26.0	36.4	28.0	20.5	28.0	28.0
Drawn for 18 Hrs.									
M	40.0	49.7	35.5	38.3	34.6	3.8	30.4	37.1	2.8
S	39.0	51.9	34.7	37.4	38.4	3.8	28.0	31.9	1.8
C	37.8	69.7	63.1	29.3	37.8	3.7	24.7	7.9	1.7
N	28.1	46.1	50.8	23.4	43.4	28.8	14.8	30.8	37.8
V	41.6	28.3	40.4	34.4	28.4	39.1	29.8	24.0	16.0
MN	30.8	37.8	39.8	27.8	37.1	34.6	20.0	25.4	28.8
Drawn for 36 Hrs.									
M	37.4	53.3	33.0	34.8	38.3	2.8	30.8	30.7	2.0
S	37.8	48.5	25.2	29.1	30.6	1.6	18.8	26.7	2.6
C	41.0	70.4	17.7	28.6	2.0	1.3	12.0	4.0	1.6
N	24.1	44.4	41.7	21.3	37.9	26.3	19.7	36.6	36.4
V	39.8	29.1	36.0	36.7	27.5	24.9	31.0	27.8	22.2
MN	27.7	34.9	31.3	27.7	25.5	25.4	25.6	26.2	17.3

NOTE: Each figure represents the average of 2 tests.

It was felt at the outset that this part of the test would not be of much value, but it was run to determine, if possible, whether or not any permanent or even temporary change took place in the metal because of its subjection to the low temperature. Table 7 below gives the hardness numbers obtained.

TABLE VII

BRINELL NUMBERS

SYMBOL	LOCATION					
	WELD		ADJACENT		PLATE	
	Before Cooling	After Cooling	Before Cooling	After Cooling	Before Cooling	After Cooling
2M	109	109	116	116	109	112
6M	104	106	121	118	104	109
12M	114	109	121	116	106	104
36M	109	109	116	121	106	106
2S	114	112	116	121	114	114
6S	114	112	121	118	114	116
12S	112	114	116	120	114	116
36S	109	104	116	114	112	109
2C	114	109	98	94	83	86
6C	107	109	90	92	88	88
12C	109	107	87	90	82	83
36C	104	101	82	83	83	80
2N	152	166	141	141	130	143
6N	176	166	161	157	135	136
12N	176	168	166	156	135	131
36N	170	165	156	151	131	136
2V	180	123	125	128	125	121
6V	120	116	123	120	121	116
12V	119	121	116	124	116	120
36V	125	124	123	121	120	118
2NS	168	179	161	166	151	154
6NS	179	168	164	168	154	161
12NS	161	156	168	159	154	159
36 NS	156	170	168	170	154	161

Analysis

A chemical analysis was made of each plate and each weld for the elements listed below. These elements were chosen because they seemed to be the ones which played the most important part, among the more common elements, in affecting the impact resistance of steel at low temperatures.

The complete analysis of each steel and weld is given in Table 8.

The question was raised as to whether the analysis of the heat-affected area of the plate was changed due to the intense heat of the arc. A check analysis showed that no chemical change had taken place.

TABLE VIII

CHEMICAL ANALYSIS

SYMBOL	C	Mn	P	S	Si	Ni	Va	Mo	Cr
PM	.16	.68	.014	.024	.06	.15	.01	.25	.07
2M	.09	.61	.025	.018	.15	.09	.01	.24	.03
6M	.07	.61	.026	.015	.25	.09	.01	.25	.03
12M	.07	.61	.024	.015	.31	.02	.01	.25	.05
36M	.05	.60	.028	.019	.25	.06	trace	.30	.06
PS	.22	.63	.016	.029	.21	.07	.01	trace	.02
2S	.10	.59	.030	.030	.27	.08	.01	"	.05
6S	.07	.57	.022	.034	.21	.04	.02	"	.05
12S	.11	.61	.024	.032	.23	.07	.01	"	.05
36S	.07	.59	.028	.034	.25	.07	.01	"	.05
PC	.09	.43	.018	.024	trace	.02	Nil	trace	trace
2C	.06	.44	.022	.032	.19	.10	.01	"	"
6C	.07	.41	.020	.028	.17	.06	.01	"	"
12C	.07	.43	.013	.034	.18	.15	.02	"	"
36C	.05	.50	.030	.033	.15	.13	.01	"	"
PN	.28	.60	.022	.025	.22	2.19	.02	trace	.07
2N	.14	.61	.026	.030	.32	1.27	.24	"	.05
6N	.09	.54	.024	.022	.26	1.22	.21	"	.05
12N	.07	.59	.026	.027	.29	1.12	.20	"	.06
36N	.08	.56	.027	.028	.31	1.21	.14	"	.05
PNH	.17	.44	.010	.023	.19	3.72	trace	.01	.05
2NH	.05	.49	.022	.030	.27	1.78	.10	trace	.05
6NH	.09	.50	.024	.040	.28	1.76	.11	"	.06
12NH	.10	.55	.023	.038	.24	1.64	.10	"	.06
36NH	.11	.53	.021	.034	.24	1.73	.07	"	.05
PV	.16	1.16	.013	.030	.16	.12	.19	trace	.11
2V	.07	.66	.030	.027	.32	.11	.25	"	.12
6V	.07	.67	.022	.025	.36	.10	.25	"	.11
12V	.11	.71	.024	.035	.34	.03	.27	"	.06
36V	.10	.78	.022	.034	.33	.06	.24	"	.10

Microstructure

It was felt that grain size, as well as chemical analysis, would play a very important part in contributing to the impact resistance of the materials at any temperature.

Consequently, a thorough microscopic examination was made, which included the plate, the weld and the adjacent area of each type of steel after each heating period. All micrographs were taken at 100 ×, etchant—5% alcoholic nitric.

The following 72 micrographs (see Figs. 4 and 5) show the grain size of the three zones of each steel at room temperature after a 2-hr., 6-hr., 12-hr. and 36-hr. heat-treatment at 1200° F. The number appearing under each micrograph indicates the ft.-lb. absorbed by the specimen in the particular location shown in the micrograph at −50° F. In this way, a direct comparison may be made between grain size at room temperature and impact resistance at −50° F.

Discussion

From an inspection of the foregoing data, it is apparent that the tensile properties of none of the steels and of only the nickel weld are very much affected by the prolonged soaking time. In the case of the N weld, the tensile strength and yield point are materially decreased and the elongation and reduction of area materially increased by prolonging the soaking time from 2 hrs. to 6 hrs. The tensile properties of all the steels and welds, except the 2N weld, are quite acceptable from a design point of view. It will be noted that the tensile properties of the NH steel behave exactly opposite to those obtained on the other steels with respect to soaking time, that is, the tensile strength and yield point increase, and the elongation and reduction of area decrease, as the soaking time increases. In order to explain this phenomenon, additional experiments were run, and it was finally determined that the lower critical temperature of the NH steel was very close to the soaking temperature used and that when the samples were held for increasing lengths of time the formation of carbides was increased, so that the resulting hardness of the test specimens was also increased.

The Charpy tests show no marked improvement in impact resistance for any of the steels (with the possible exception of the N steel at −50° F.), due to the prolonged soaking time. The N and NH welds do, however, show some improvement.

In the case of the C steel, a very decided drop in impact resistance was noted on some of the 36-hr. specimens. This was due to a very noticeable grain growth which will be discussed more fully under microstructure.

The Brinell tests showed that no change in hardness took place due to exposure to −50° F. They also show that the large-grained 36-hr. C specimens were softened very slightly below those which had received a shorter soaking time. This checks the results obtained on the tension tests.

The analyses show the elements to remain quite constant for any given weld or plate. They also show the amount of the elements not called for in the specification to be very small; so small in fact, that they need not be considered.

Microstructure.—The micrographic study shows conclusively that the grain size plays a very important part in controlling the impact resistance of a material. The smaller the grain the better the impact resistance in any one of the steels tested. Apparently, large ferritic grains have the lowest impact resistance at low temperature. It will be noted that there is an abundance of ferrite in the plate specimens of the M, S and C steels, while in the N, NH and V steels, although there is still a predominance of ferrite, it is more generally interspersed with pearlite. The grain size, incidentally, is also smaller in the latter steels.

Referring to the M, S and C steels, it will be noted that in the adjacent area of the plate, where the grain has been refined from the welding heat, the impact resistance is a great deal higher than in the plate itself. The smaller grain size is unquestionably responsible for this change. The dispersion of pearlite throughout the structure is also very noticeable.

A predominance of ferrite does not seem to affect the impact resistance at atmospheric temperature, as will be noted from the C plate, which has the most ferrite and largest grains and yet shows the highest impact resistance at atmospheric temperature, except in the case of the 36C plate specimen.

Referring now to the 12C and 36C micrographs showing the adjacent areas of the C steel for the 12-hr. and 36-hr. soaking times, it will be noted how decidedly the low-temperature impact resistance dropped as compared to that obtained in the adjacent area of the 2C and 6C specimens. This decrease in impact resistance is unquestionably due to the presence of the very large ferrite grains shown in the micrographs. These ferrite grains were developed during the long heating period, at 1200° F.

But one might well ask why such a decided grain growth took place in the 12-hr. and 36-hr. specimens of the C steel and weld at a temperature so far below the upper critical temperature.

It is a fact that grain growth will take place in a work-hardened low-carbon steel when subjected to prolonged heating at temperatures below the critical. This phenomenon occurs in steels with carbon content between 0.05 and 0.12.

Although the C steel used in this test had not been cold-worked, it, like all welded structures before stress-relief, contained shrinkage strains in and around the weld. It is felt that these strained areas helped to form nuclei from which the grain growth took place.

In cold etching some of the 36C specimens, the grains could be seen with the naked eye, appearing somewhat as spangles. In most cases they seemed to center around the edge of the weld, in some cases extending into the

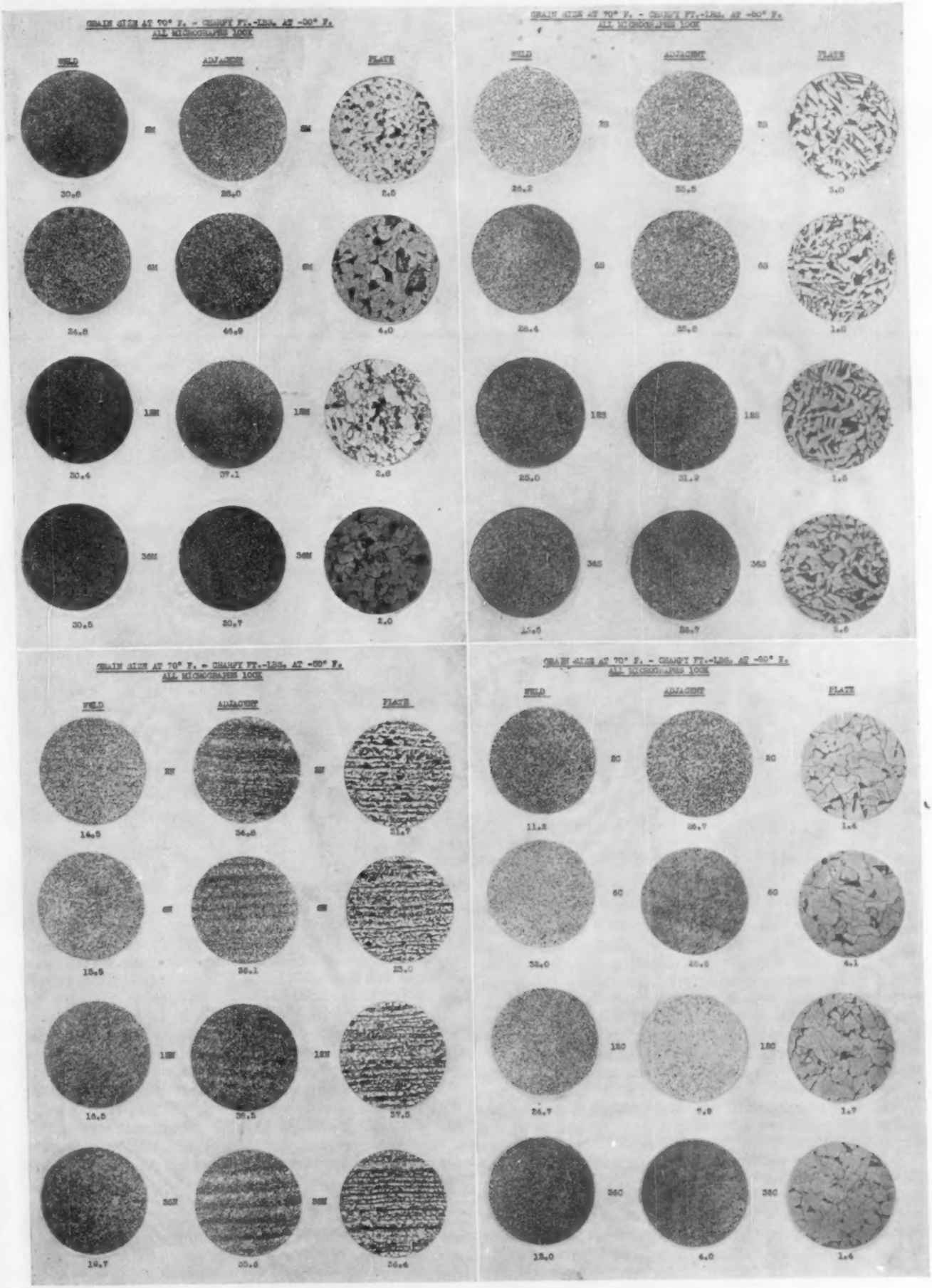

GRAIN SIZE AT 70° F. - CHARPY FT.-LBS. AT -60° F.
ALL MICROGRAPHS 100X
WELD
ADJACENT
PLATE
30.6
28.0
2.6
24.8
46.9
4.0
30.4
37.1
2.6
30.5
30.7
2.0
GRAIN SIZE AT 70° F. - CHARPY FT.-LBS. AT -60° F.
ALL MICROGRAPHS 100X
WELD
ADJACENT
PLATE
26.2
35.5
3.0
26.4
35.6
1.6
25.0
31.9
1.6
25.6
38.7
1.6
GRAIN SIZE AT 70° F. - CHARPY FT.-LBS. AT -60° F.
ALL MICROGRAPHS 100X
WELD
ADJACENT
PLATE
14.5
34.6
21.7
15.9
36.1
23.0
16.6
36.5
37.5
19.7
35.6
26.4
GRAIN SIZE AT 70° F. - CHARPY FT.-LBS. AT -60° F.
ALL MICROGRAPHS 100X
WELD
ADJACENT
PLATE
11.2
26.7
1.6
58.0
25.6
4.1
24.7
7.9
1.7
18.0
6.0
1.4

Fig. 4

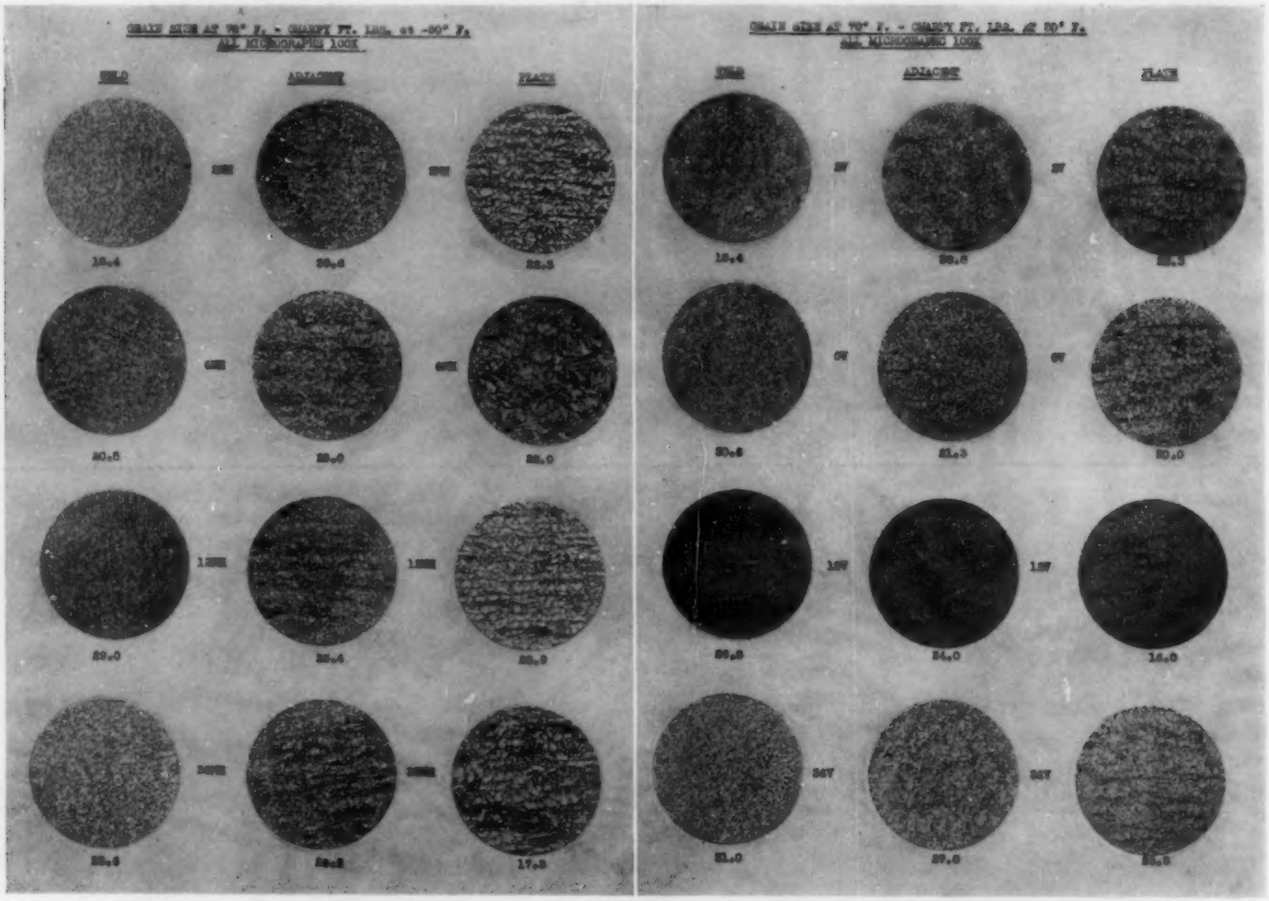
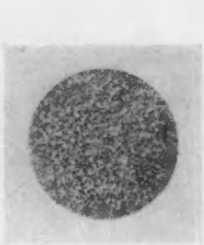


Fig. 5

plate for a short distance, and not into the weld. In other cases the reverse would be true, and in still other cases they would extend across the weld into the plate on the opposite side, while in still other cases there seemed to be no grain growth at all. Apparently, this condition localizes itself in small areas.

This phenomenon might well play a very important part in the behavior of low-carbon steels which are subjected to high temperatures operating for long periods of time. This would be particularly true if the steel had been cold-worked, or was even under an initial high strain. This point could well stand serious consideration.



3 Steel

Grain Size at 70° F.–Charpy Ft.-Lb. at −50° F. All Micrographs 100×

50.3

Fig. 6

Conclusions

1. The M, S or C plate, as-rolled and soaked, is not suitable for low-temperature operation where shock is a factor, regardless of soaking time.

NOTE: Subsequent tests indicate that when molybdenum steel is properly made and treated, it shows considerable promise. Low-carbon and medium-carbon steels, however, are definitely not acceptable.

2. The N plate, on the contrary, is quite satisfactory for this service for any of the soaking times tested. The V and NH plates are also acceptable, but neither shows as good results as the N plate.

3. All of the welds tested (for at least one soaking time) are acceptable for service at −50° F., the preference being in the following order: V, M, S, C, NH and N.

4. Grain size very decidedly affects the impact resistance at all temperatures. The smaller the grain the higher the impact resistance for any single steel tested. A predominance of large-grained ferrite seems to be detrimental to good low-temperature impact resistance, while a fine-grained well-dispersed pearlitic structure is distinctly beneficial.

5. Chemical analysis contributes as much, or more, toward the control of impact resistance, than grain size.

6. Nickel and vanadium each tend to produce good low-temperature impact resistance.

7. The low-temperature impact resistance of the $3^1/_2\%$ nickel steel is no better than that of the $2^1/_4\%$ nickel steel.

8. Prolonged soaking time at 1200° F. does not improve the low-temperature impact resistance of M, S, C or V steels.

9. Prolonged soaking time does improve low-temperature impact resistance of the N steel somewhat. This is also true for the NH steel, except in the case of the 36-hr. specimen, which is lower than either of the other three specimens. The N and NH welds are improved by the

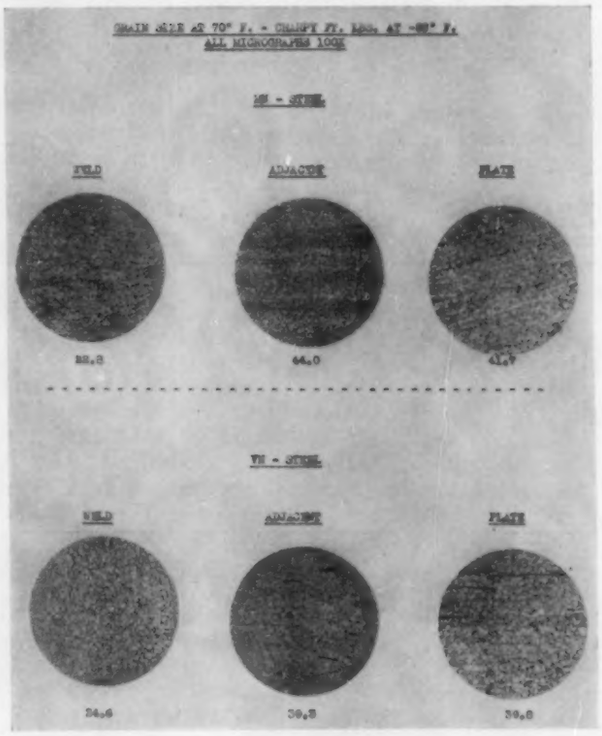


Fig. 7

increase in soaking time, but in no case is either of these welds as good as other welds tested.

10. Brinell hardness does not change because of exposure to −50° F. for a period of 1 hour.

11. The results of these tests indicate that the best welded structure would be obtained by welding the N plate with the M or V weld, but such a weld must be made and tested before a definite conclusion can be drawn as to the effectiveness of this procedure.

PART II—Molybdenum and Vanadium Welds on Nickel Steel Plate

After the foregoing work was finished, it was decided to investigate the possibilities of welding $2^1/_4\%$ nickel steel with the M rod and with the V rod. Accordingly, some $2^1/_4\%$ nickel steel plate was welded with the same rods used in the previous test for the M plate and for the V plate, respectively, except that the amounts of molybdenum and vanadium were increased slightly to compensate for the lack of these elements in the nickel plate. This was done with the idea of maintaining approximately the same molybdenum and vanadium content as was obtained in the previous welds when molybdenum and vanadium plates were used. The properties obtained follow:

Tensile Properties

Symbol	T.S.	Y.P.	Elong. in 2 In.	R. A.
4VNW	73750	42300	27.0	57.8
4VNP	66650	41000	34.0	59.1
4MNW	59750	41450	34.0	64.7
4MNP	66250	42000	35.0	60.8

Impact Test, Charpy Ft.-Lb. Absorbed

	+70° F.			−25° F.			−50° F.		
Symbol	Weld	Adj.	Pl.	Weld	Adj.	Pl.	Weld	Adj.	Pl.
4VN	26.1	35.5	44.9	23.3	41.7	39.8	24.6	39.3	39.8
4MN	32.3	42.0	39.3	23.6	42.8	23.3	22.8	44.0	41.7

NOTE: Each figure represents the average of two tests.

No Brinell numbers were taken as the previous tests showed no appreciable change.

Chemical Analysis

Symbol	C	Mn	P	S	Si	Ni	V	Mo
PN	0.14	0.56	0.020	0.025	0.21	2.04	..	..
WVN	0.07	0.53	0.023	0.035	0.35	0.28	0.31	..
WMN	0.08	0.48	0.023	0.024	0.24	0.39	..	0.57

Discussion

The tensile properties of weld and plate are normal. The tensile strength of the plate is lower than that obtained in the previous test, but this is due to its lower carbon content.

The low-temperature impact resistance of the plate is somewhat better than that obtained in the first test. It is felt that this is also due to the lower-carbon content of the plate material.

It will be noted that the impact resistance of the adjacent area for the various temperatures is practically the same as that obtained in the plate. In the other steels tested, the adjacent area was usually much better than the plate, but as stated above the plate in this test has a better low-temperature impact resistance than the plates in the previous test.

One might, therefore, conclude that the high values obtained in the present plate were because of an exceptionally small grain in the plate, corresponding to the grain in the adjacent area. But an inspection of the micrographs shows this not to be the case, as the grain size of the plate and the adjacent area are practically identical to those obtained in the previous tests on the other nickel steel (see Fig. 7).

It, therefore, follows that the effect of grain-size in a low-carbon nickel steel is much less sensitive in changing the low-temperature impact resistance than it is in a higher-carbon nickel steel, or in any of the other steels tested.

Attention is called to the almost constant impact resistance of the plate material at +70°, −25° and −50° F. This condition was not obtained in any of the other steels, but is, however, one to be desired.

Referring now to the welds, it will be noted that the low-temperature impact resistance of both the VN and MN welds is better than that obtained on the N or NH weld, but not as good as that obtained on the V and M welds when welding V and M steel, respectively.

No definite explanation is available for the drop in impact resistance of these welds. Since the micrographic study gives no clue, it is felt that the particular chemical combination of the elements is responsible.

It is interesting to note that the impact resistance of the VN weld at −50° F. (24.6) is practically the same as the average of the V and N welds obtained in the first test at −50° (22.6). The impact resistance of the MN weld of 22.8 compares even more closely to the average of the M and N welds (22.7). This is not necessarily an explanation for the point in question, but is considered rather interesting.

Conclusion

1. The low-temperature impact resistance of a vanadium or molybdenum weld on a 2¼% nickel steel plate, although acceptable, is not as good as that obtained on the same welds while welding vanadium and molybdenum steel plates, respectively.

Part III

Manganese Steels

At the time the foregoing tests were in progress, certain investigators were making claims regarding the value of manganese steels for this type of service. It was, therefore, decided to test three grades of manganese steel. These steels were: 1¼% manganese with low silicon; 2% manganese with medium silicon; and 1½% manganese with high silicon. The analysis of these three steels follows:

	Carbon	Manganese	Phosphorus	Sulphur	Silicon
1.	0.24	1.20	..	..	0.03
2.	0.24	2.10	..	..	0.14
3.	0.21	1.54	0.02	0.03	0.37

Test Procedure

This test covered the investigation of impact resistance of steel plate only. No welding tests were made. The steels were tested in the as-rolled, in the drawn, in the annealed and in the annealed and drawn condition. The first two steels listed were tested at +70° F., −25° F. and −50° F., while the last steel was tested at −75° F. only. The first steels were held at temperature for one hour before testing, while the last steel was held for various lengths of time, namely, 2 hrs., 4 hrs., 6 hrs. and 8 hrs.

Test Results

The table below shows the Charpy impact results in ft.-lb., absorbed for each of the steels and treatments:

Charpy Ft.-Lb. Absorbed

Steel		Treatment		Held at Low Temp.,	Temperature of Test, ° F.			
Mn	Si	Anneal	Draw	Hrs.	+70	−25	−50	−75
1.20	0.03	..	..	1	39.0	3.2	3.0	..
1.20	0.03	..	..	1	39.5	24.0	3.0	..
1.20	0.03	..	..	1	47.0	4.0	27.3	..
1.20	0.03	..	..	1	44.0	13.2	3.0	..
1.20	0.03	..	1200	1	29.0	6.0	2.5	..
1.20	0.03	..	1200	1	12.0	2.5	3.0	..
1.20	0.03	..	1200	1	33.0	3.5	3.0	..
1.20	0.03	..	1200	1	30.0	9.5	16.0	..
1.20	0.03	1350	1200	1	43.0	39.5	3.2	..
1.20	0.03	1350	1200	1	48.0	5.0	4.5	..
1.20	0.03	1350	1200	1	46.0	14.5	30.0	..
1.20	0.03	1350	1200	1	39.0	32.5	3.5	..
1.20	0.03	1450	1200	1	..	30.7	24.0	..
1.20	0.03	1450	1200	1	..	4.0	23.0	..
1.20	0.03	1450	1200	1	..	..	4.0	..
1.20	0.03	1450	1200	1	..	..	3.5	..
2.10	0.14	..	..	1	8.5	4.0	3.5	..
2.10	0.14	..	..	1	8.5	4.0	2.0	..
2.10	0.14	..	..	1	7.0	3.3	3.0	..
2.10	0.14	..	..	1	..	3.5	3.0	..
2.10	0.14	..	1200	1	18.0	11.0	7.8	..
2.10	0.14	..	1200	1	20.0	12.0	7.0	..
2.10	0.14	..	1200	1	17.5	17.0	4.5	..
2.10	0.14	..	1200	1	..	10.4	7.2	..
2.10	0.14	1450	1200	1	25.0	27.5	26.0	..
2.10	0.14	1450	1200	1	39.5	15.0	13.0	..
2.10	0.14	1450	1200	1	44.0	20.5	16.0	..
1.54	0.37	..	..	2	..	..	..	3.4
1.54	0.37	..	..	2	..	..	..	2.6
1.54	0.37	..	..	2	..	..	..	2.5
1.54	0.37	..	..	4	..	..	..	3.0
1.54	0.37	..	..	4	..	..	..	5.0
1.54	0.37	..	..	4	..	..	..	2.4
1.54	0.37	..	..	6	..	..	..	7.4
1.54	0.37	..	..	6	..	..	..	3.8
1.54	0.37	..	..	6	..	..	..	2.9
1.54	0.37	..	..	8	..	..	..	3.0
1.54	0.37	..	..	8	..	..	..	3.5
1.54	0.37	..	..	8	..	..	..	2.6
1.54	0.37	1550	..	2	..	..	..	2.0
1.54	0.37	1550	..	2	..	..	..	4.8
1.54	0.37	1550	..	2	..	..	..	1.6
1.54	0.37	1550	..	4	..	..	..	1.5
1.54	0.37	1550	..	4	..	..	..	1.6
1.54	0.37	1550	..	4	..	..	..	1.6
1.54	0.37	1550	..	6	..	..	..	2.4
1.54	0.37	1550	..	6	..	..	..	2.5
1.54	0.37	1550	..	6	..	..	..	3.1
1.54	0.37	1550	..	8	..	..	..	1.8
1.54	0.37	1550	..	8	..	..	..	1.6
1.54	0.37	1550	..	8	..	..	..	1.8
1.54	0.37	1550	1200	2	..	..	..	2.9
1.54	0.37	1550	1200	2	..	..	..	2.5
1.54	0.37	1550	1200	2	..	..	..	3.0
1.54	0.37	1550	1200	4	..	..	..	2.4
1.54	0.37	1550	1200	4	..	..	..	2.5
1.54	0.37	1550	1200	4	..	..	..	3.1
1.54	0.37	1550	1200	6	..	..	..	3.1
1.54	0.37	1550	1200	6	..	..	..	17.9
1.54	0.37	1550	1200	6	..	..	..	4.5
1.54	0.37	1550	1200	8	..	..	..	2.2
1.54	0.37	1550	1200	8	..	..	..	3.0
1.54	0.37	1550	1200	8	..	..	..	2.5

Discussion

It will be seen from the above table that none of the three steels is acceptable at sub-zero temperatures when tested in the as-rolled, or in the as-rolled and drawn condition. Although annealing and drawing improve all three of the steels somewhat, the treatment does not bring the impact resistance up to the necessary minimum. The 2.10% manganese steel showed the highest average result of any of the three steels tested in the annealed and drawn state.

It is quite evident that manganese steel is extremely erratic from a standpoint of impact resistance at low temperature. It is felt that with exactly the proper heat treatment, small pieces can be put into a condition which is acceptable, but it is also felt that it would be entirely impractical to heat-treat large sections such as as-rolled plates, or even large castings, with the required delicacy to insure good impact resistance throughout the section.

Conclusion

It is concluded from the above data that manganese steel cannot be used safely at sub-zero temperatures.

NOTE: Since the above tests were run, word has been received that one investigator still claims good low-temperature impact resistance for manganese steel. In view of this and in view of the rather meager data at hand, it is desired that the above conclusion be withheld until further data are collected. A series of tests on several grades of manganese steels is now in progress. Some 1200 impact bars are to be broken on this test, and it is felt that after this is done a definite conclusion may be drawn concerning the value of this steel for low-temperature service. When this work is finished, the findings will be reported in a supplementary paper.

PART IV

Fabrication of a Nickel Steel Vessel

As stated in the first part of this report, a full-sized tank was to be welded of the steel which showed the most promise after the tests were completed. In view of the above data, the $2^1/_4\%$ nickel steel was adopted, and a tank 48 in. I.D. x 8 ft. long x $1^1/_4$ in. thick was made under regular shop conditions. This tank included two 8-in. nozzles and one 20-in. manway, as shown in Fig. 8.

The manway and one 8-in. nozzle were placed on the shell, the former being reinforced with a flat plate and welded clear through, the latter having integral reinforcement. One 8-in. plate reinforced nozzle was welded in the center of one head.

One of the heads was spun in the normal way at the steel mill, that is, heated to 1950° F., spun and air-cooled. The other head, however, was normalized at 1625° F., after the first spinning operation, after which it was respun to shape. This was done so that the impact properties at low temperature of these two heads could be compared.

After completion, the tank was stress-relieved in the normal way. All longitudinal and girth welds were X-rayed after stress-relieving. A cost comparison, including an accurate time study of each operation was made. Physical tests included the normal tensile and bend tests at room temperature, and impact tests at room temperature and at −50° F. All of these tests were run on weld metal, shell plate, head plate and manway weld and neck.

Procedure

In order to obtain as much data as possible from this one tank, the shell was made to contain two longitudinal welds. One made with one type of electrode designated as No. 1 and the other made with another type of electrode designated as No. 2. The two head seams were welded similarly. The manway and nozzle welds were made with electrode No. 2. Very little trouble was experienced during any of the welding. Complete X-ray examination of all main seam welds was made after their completion. After these two seams were welded, and before the nozzles and manway were welded to the tank, it was stress-relieved in the usual manner at 1150° F. for one hour per inch of thickness. These seams were re-X-rayed after stress-relief.

The 20-in. manway and the two 8-in. nozzles were then welded to the tank. No trouble whatever was experienced with this welding. After completion of these fittings, the tank was again stress-relieved.

A very accurate time study was made during all of the welding operations, with the idea of comparing the cost of the two types of weldrods used, and also to compare these with the cost of welding regular carbon steel tanks. A summary of this study follows:

Table 9—Comparison of No. 1 and No. 2 Electrodes

Item	Longitudinal Seams		Circular Seams	
	No. 1	No. 2	No. 1	No. 2
Net volume of groove in cu. in.	66.8	67.2	86.6	91.6
Volume of rods consumed	82.8	82.9	109.0	109.8
Spatter and chip loss, cu. in.	16.0	15.7	22.3	18.2
Total loss in per cent	19.3	19.0	26.0	19.9
Excess time required by No. 1	16.2%		16.2%	
Excess cost/cu. in. reqd. by No. 1	12.3%		22.0%	

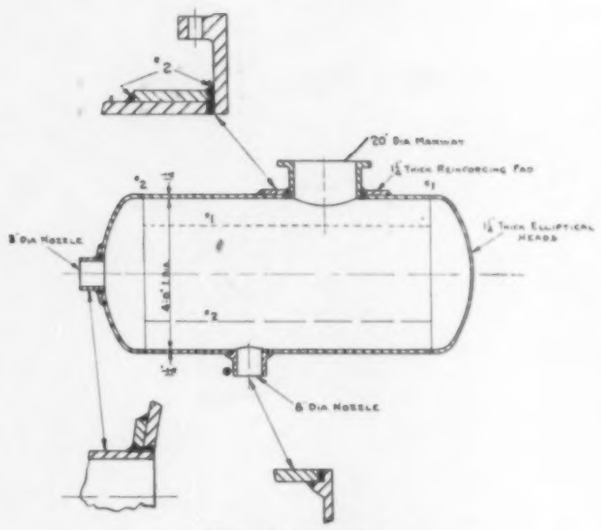


Fig. 8—Nickel Steel Tank

Cracks during welding:				
	In.	In.		
1st layer	36	18	2 small ones	2 small ones
2nd layer	24	..	.....	.....
3rd layer	24	..	.....	.....
X-ray	Perfect	3 small defects	Perfect	Some slag in 1st layer

A section of the manway neck was removed so that an X-ray examination could be made of the main weld. This examination revealed a perfect weld.

Tests

The shell plate and the heads were furnished by the Lukens Steel Company from their heat No. 12794. The manway and nozzles were furnished by Taylor Forge Company from steel furnished them by Lukens.

Chemical analysis, tensile and bend properties, impact properties at room temperature and at −50° F. and micrographic and macrographic structures of the various parts were obtained. The following table gives the chemical analyses of these parts:

Table 10—Chemical Analyses

		C	Mn	P	S	Si	Ni	Mo
No. 1 Weld	Long.	0.09	0.39	0.029	0.036	0.19	0.45	None
	Cir.	0.09	0.46	0.014	0.033	0.20	0.45	None
No. 2 Weld	Long.	0.10	0.44	0.070	0.015	0.05	2.25	0.15
	Cir.	0.14	0.46	0.070	0.013	0.07	2.25	0.27
Plate		0.14	0.57	0.025	0.028	0.17	2.16	....
Normal head		0.14	0.59	0.024	0.030	0.16	2.18	....
Head treated		0.13	0.58	0.023	0.027	0.17	2.16	....
Manway		0.24	0.64	0.029	0.030	0.21	2.55	....

Tensile and bend properties, as well as impact properties, are listed in Table 11.

Table 11—Physical Properties—0.505 In.

Location	T.S.	Y.P.	Elong. in 2 In.
Cir. weld No. 1	88,600	76,100	21.0
Cir. weld No. 2	70,000	58,500	23.5
Long. weld No. 1	72,100	53,650	28.0
Long. weld No. 2	70,150	51,500	32.0
Plate	68,750	47,300	36.0
Normal head	69,000	43,500	33.0
Treated head	68,200	44,000	35.0
Manway weld	74,700	64,500	26.5
Manway weld	75,200	65,600	24.0
Fillet weld	85,000	71 200	24.5

Table 11—Continued

Reduced Tensile and Bend Tests

Item	No. 1	No. 2
Reduced tensile	72,700	70,500
Bend bar	45.0%	65.0%

Charpy Impact Tests

Location	+70° F.		−50° F.	
Circular weld No. 1	20.3, 19.6, 22.7	20.9	15.8, 19.3, 16.2	17.1
Adjacent area No. 1	40.3, 45.0, 37.2	40.8	38.1, 27.6, 45.8	37.2
Circular weld No. 2	28.3, 28.0, 23.7	36.7	18.2, 17.0, 19.2	18.1
Adjacent area No. 2	40.0, 37.6, 42.2	39.9	28.6, 38.1, 37.2	34.6
Longitudinal weld No. 1	28.0, 31.5, 23.2	27.6	16.3, 16.7, 20.0	17.7
Adjacent area No. 1	41.2, 45.0, 47.0	44.4	25.0, 25.4, 46.0	32.1
Longitudinal weld No. 2	28.1, 26.5, 26.1	26.9	16.6, 17.4, 17.3	17.1
Adjacent area No. 2	34.7, 41.2, 49.1	41.3	28.3, 36.2, 35.6	33.4
Manway weld No. 2	26.2, 26.0, 25.8	26.0	16.4, 17.8, 16.7	16.9
Fillet weld No. 2	19.1, 31.0, 28.7	26.3	24.2, 16.1, 15.6	18.6
Plate, longitudinal	46.8, 42.2, 44.2	44.4	31.2, 40.0, 37.2	36.1
Plate, transverse	40.1, 37.8, 45.2	40.8	48.2, 31.8, 72.0	50.7
Normal head, longitudinal	35.2, 32.6, 33.3	33.7	21.0, 21.8, 27.2	23.3
Normal head, transverse	23.7, 24.7, 22.4	23.6	23.1, 26.8, 18.7	22.9
Heat-treated head, longitudinal	38.2, 37.7, 40.2	38.7	36.2, 31.2, 35.2	34.2
Heat-treated head, transverse	28.2, 26.7, 33.8	29.6	26.7, 24.2, 24.8	25.2
Manway neck, stress-relieved	16.0, 17.1, 17.0	16.7	7.1, 7.9, 7.4, 5.9	7.1
Manway neck, normalized at 1550°, stress-relieved at 1150° F.	18.2, 21.1, 19.9	19.7	14.1, 11.4, 14.5, 12.7	13.2
Manway neck, normalized 1750°, 4 hrs.; normalized 1550° F., 1 hr.; stress-relieved 1150° for 1 hr. furnace-cooled	20.3, 18.5, 20.4	19.7	12.5, 11.1, 13.5, 8.9	11.5

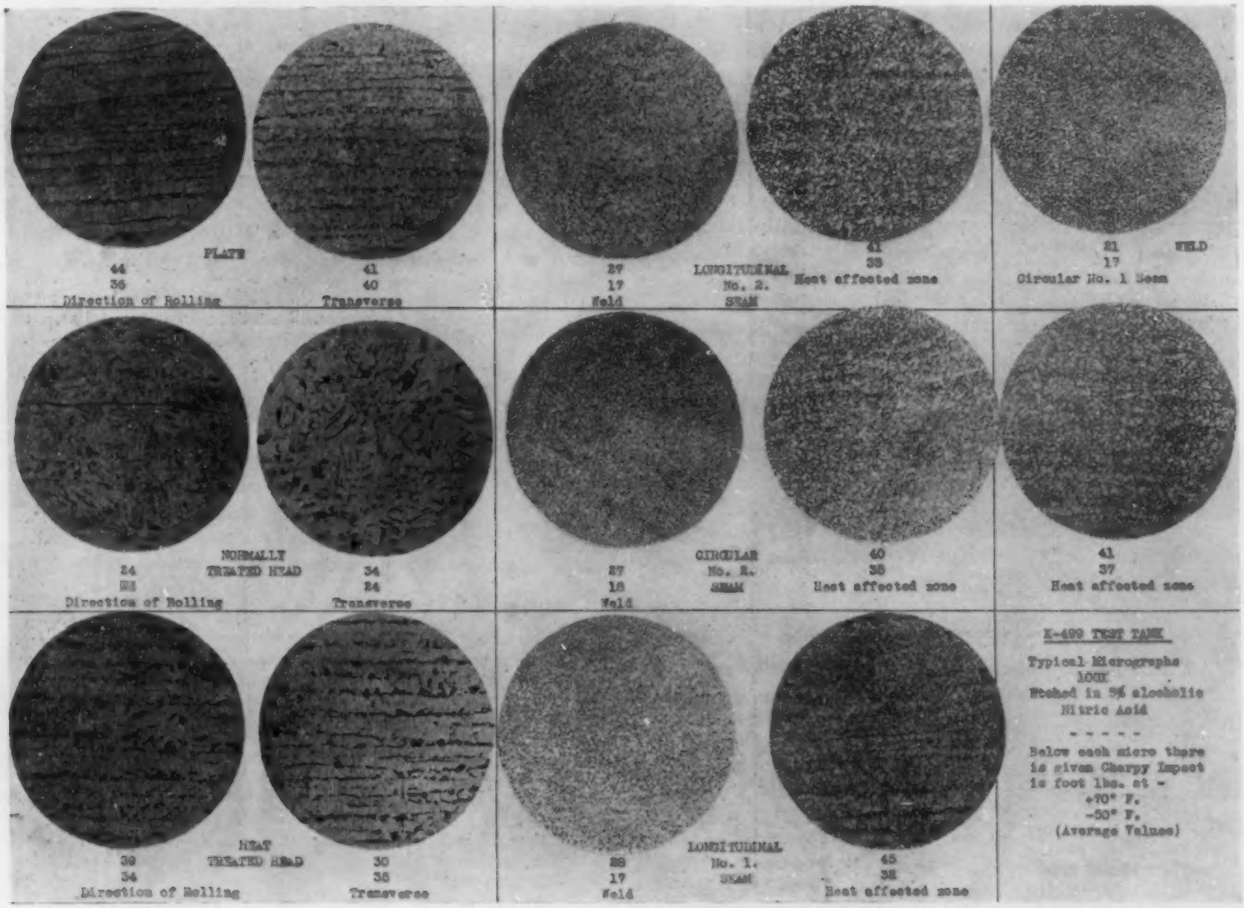


Fig. 9

Micrographs at 100× from various parts of the plate and manway materials and welds are shown in Figs. 9 and 11.

Discussion

An inspection of Table 9 shows clearly that the No. 2 rod is the more economical for this type of work. It also indicates that it is preferable from a welding point of view, because of the tendency of the other rod to crack.

Table 11 shows very good tensile and bend properties for plate, heads and weld metal, except that the tensile strength of the plate materials is slightly below the minimum requirement of 70,000 lb. per sq. in. This is due to the very low-carbon content of the plate.

The data on impact properties indicate that there is no choice between welds made by the No. 1 or No. 2 rods, the values being quite acceptable in all cases. It is interesting to note in this connection that the large amount of nickel contained in the No. 1 welds does not improve the impact properties over those obtained by the low-nickel bearing No. 2 welds.

The impact properties of the adjacent areas, as usual, are very high. The impact properties of the plate and heads lie between those of the adjacent area and those of the weld.

It is clearly shown that the low-temperature impact properties of the heat-treated head are considerably higher than those of the un-heat-treated head. This is an important point because it provides a definite control over the impact properties of this part of the pressure vessel.

The difference in low-temperature impact properties between transverse and longitudinal bars is not very marked, except in the case of the heat-treated head. The properties in both directions are acceptable.

It is particularly interesting to note the low-impact properties obtained on the manway neck, especially when the analysis is compared with that of the plate; it being practically the same.

An inspection of Photograph No. 3253 (Fig. 10) as well as the micrographs of this specimen (see Fig. 11) shows a distinctly dendritic structure. Even in the normalized and double normalized state, this condition still persisted. The low-impact properties can be probably accounted for by the presence of this structure.

At first, it was not understood how this structure could exist in a forged steel manway neck but, on checking back on the source of the steel and the history of its fabrication, it was found that the neck had been forged but very little, it having been almost entirely machined from a nickel steel slab. Since a slab of such great thickness will of necessity have received a very small amount of mechanical work on the rolling mill, its structure will be dendritic, showing distinct signs of ingotism. As this structure is most undesirable, it having been shown that even heat treatment will not entirely remove it, it becomes necessary in buying such parts to guard against the delivery of this type of material by properly written specifications.

Fig. 10

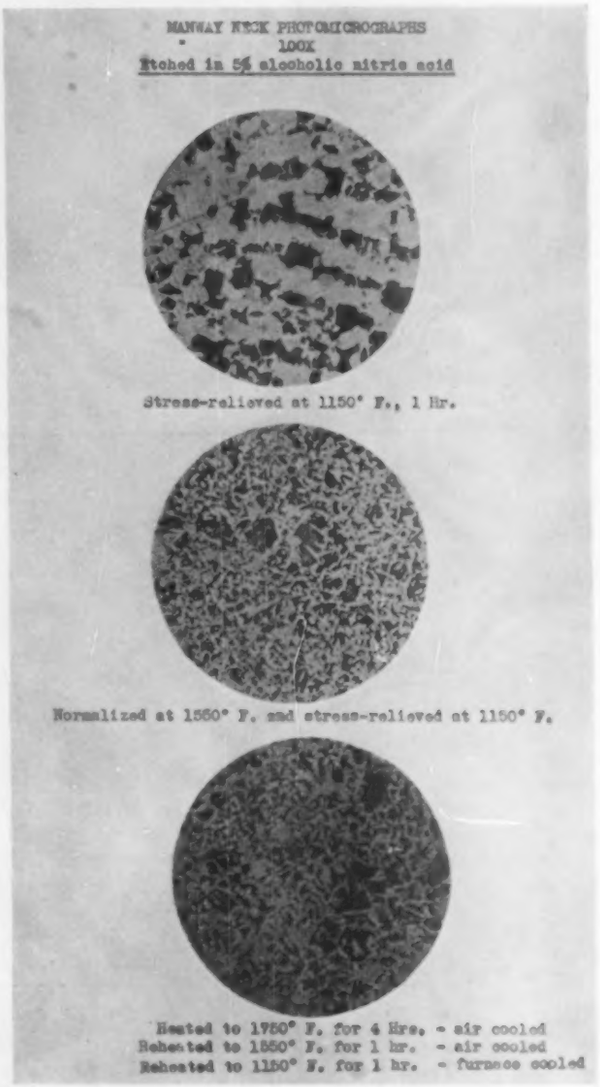

MANWAY NECK PHOTOMICROGRAPHS
100X
Etched in 5% alcoholic nitric acid
Stress-relieved at 1150° F., 1 Hr.
Normalized at 1650° F. and stress-relieved at 1150° F.
Heated to 1750° F. for 4 Hrs. - air cooled
Reheated to 1550° F. for 1 hr. - air cooled
Reheated to 1150° F. for 1 hr. - furnace cooled

Fig. 11

The macrographs (see Fig. 12) and micrographs of plate, heads and welds (see Fig. 9) show a typical structure for the areas investigated. Those of the manway neck, however, show very distinctly the condition described above.

Field Welds

Several girth welds were made on 12 in. x $^1/_2$ in. thick, $2^1/_4$% nickel steel pipe to simulate field welding conditions. The pipe was strapped down so that it was necessary for the welder to work his way around the joint just as he would do in the field. Rods of $^5/_{32}$-in. and $^3/_{16}$-in. diameter No. 2 electrode were used. The joints were stress-relieved locally by a circular gas-fired furnace. Each joint was X-rayed, after which impact bars were taken from weld and plate. Besides taking bars from the weld and adjacent area, a large number was taken from the pipe which had been within the furnace, that part in the transition zone between the heated area and

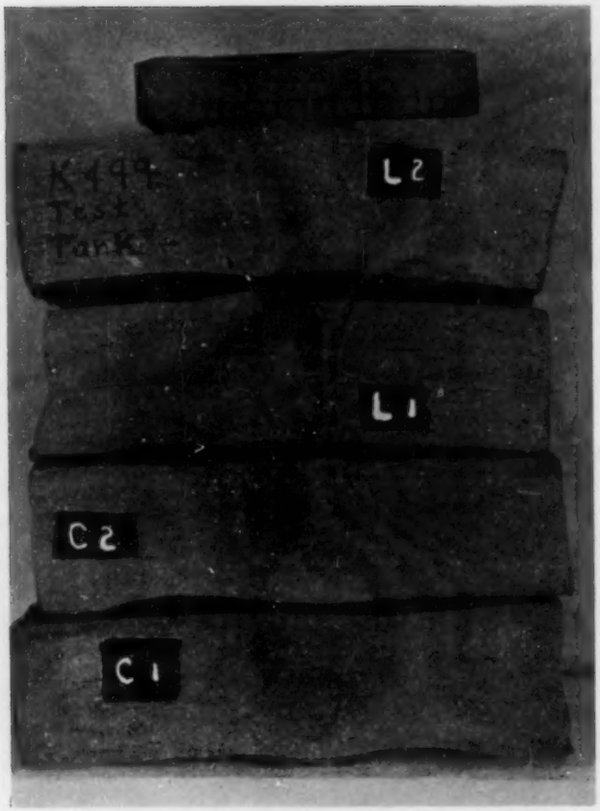


Fig. 12

the unheated area, and also from the cold unaffected part. These bars were taken on $^1/_2$-in. centers, starting from the center of the weld and extending through the stress-relieved and transition zones out into the cold part of the pipe.

The results of these tests indicated clearly that such welds can be satisfactorily made in the field, since their quality as revealed by the X-ray and other tests is quite acceptable.

Conclusions

It is concluded from the foregoing data that:

1. The welding of $2^1/_4\%$ nickel steel tanks on a production basis is entirely feasible.
2. The No. 2 electrode is faster and more economical for the welding of $2^1/_4\%$ nickel steel materials than the No. 1 electrode.
3. The impact resistance at room temperature and at $-50°$ F. of welds, made by either of the rods tested, is satisfactory.
4. High-nickel content in weld metal is not necessary to obtain good low-temperature impact resistance.
5. Normalization of hot spun $2^1/_4\%$ nickel steel heads is essential to maintain acceptable impact resistance at low temperatures.
6. It is essential to guard against materials containing dendritic structures.
7. Acceptable field welds can be made on $2^1/_4\%$ nickel steel pipe.
8. Local stress-relief of welds on $2^1/_4\%$ nickel steel pipe has no detrimental effect on the pipe.

Acknowledgments

The author wishes to express his appreciation of the interest and assistance given by H. S. Blumberg, Research Metallurgist, and J. W. Hunt, Engineer of Tests of the M. W. Kellogg Company.

Free-Bend Tests on Welds

By F. S. MAPES and F. HOWENSTEIN†

IN THE past a great deal of trouble has been encountered in attempting to make free-bend tests on welded specimens. The A. S. M. E. Boiler Code states, "The specimen is to be bent cold under free bending conditions," and to accomplish this has indicated a means of making a preliminary bend each side of the weld, it being assumed that the weld is in the exact center of the specimen. The specimen is divided longitudinally into three equal parts, and each

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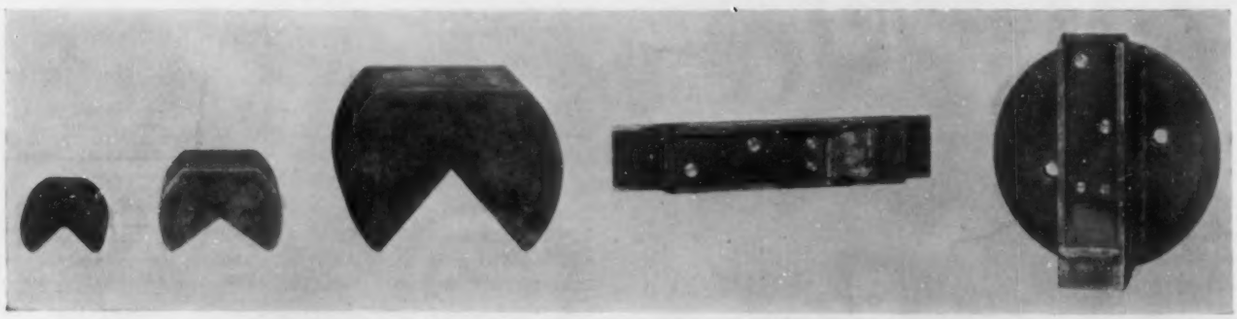
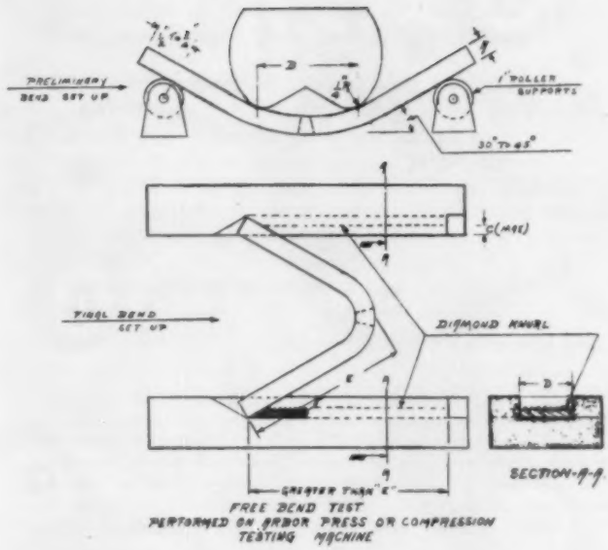


Fig. 1—Improved Fixtures for Making Preliminary Bends on Welded Specimens

Fig. 2—View Showing Knurled Grip Inserts to Prevent Slipping



A	B	C	D
1/4" TO 1/2"	1/4"	1/4"	MAXIMUM WIDTH OF SPECIMEN PLUS 1/8"
1/2" TO 2"	2"	1/2"	
OVER 2"	3"	1/4"	

Fig. 3—Method of Making Free-Bend Test on Welded Specimen

end third is bent until it is at 30° to the horizontal middle section. The specimen is then stood upright in a compression tension machine or other compression device, and compressed until the weld metal shows defects not exceeding 1/16 in. in size or until the outside fibers in the weld have stretched at least 30%.

It was felt that, in order even to approach the ideal free-bending method described above, it was necessary to have the 30° angle practically perfect. Otherwise the bend would tend to shift from the weld metal to the side of the specimen having the greatest initial bend. Even then it required many readjustments in the compression machine to maintain the maximum bend within the weld metal.

While a free-bend test is the ideal, it must be considered that in most instances the elastic limit of the plate stock, as well as its tensile strength, is below that of the weld metal. This being the case it is only natural that, unless the bending area is controlled or restricted, any free bend will come in the weaker metal, which in this case is the plate. The ideal cannot be attained with such existing conditions.

In addition to the above difficulties, it developed that different types of welds and weld metal varied in their influence on the ease with which bend tests of this nature could be made.

It was felt that, in general, the method of making free-bend tests on welded specimens could be improved considerably if a fixture could be made so that the initial angle on both ends of the specimen would be exactly the same. As a result, the loading noses shown in Fig. 1 were developed. Three sizes of noses were made, with distances between points of loading of 1 1/4, 2 and 3 in., respectively, and the choice of nose to be used was governed by the thickness of specimen to be tested. This meant that the initial bends would not come at the exact 1/3 point of the specimen, but this feature was proved to be relatively unimportant if the weld metal itself was not disturbed and was held midway between the points of loading. Using this method of making preliminary bends, it was possible to secure a greater number of satisfactory tests, but the necessity of readjustment in the compression machine still existed,

Fig. 4—Welded Specimens after Free-Bend Tests When Using Old-Type Fixtures. Misalignments Result from Specimen Slipping in Fixture

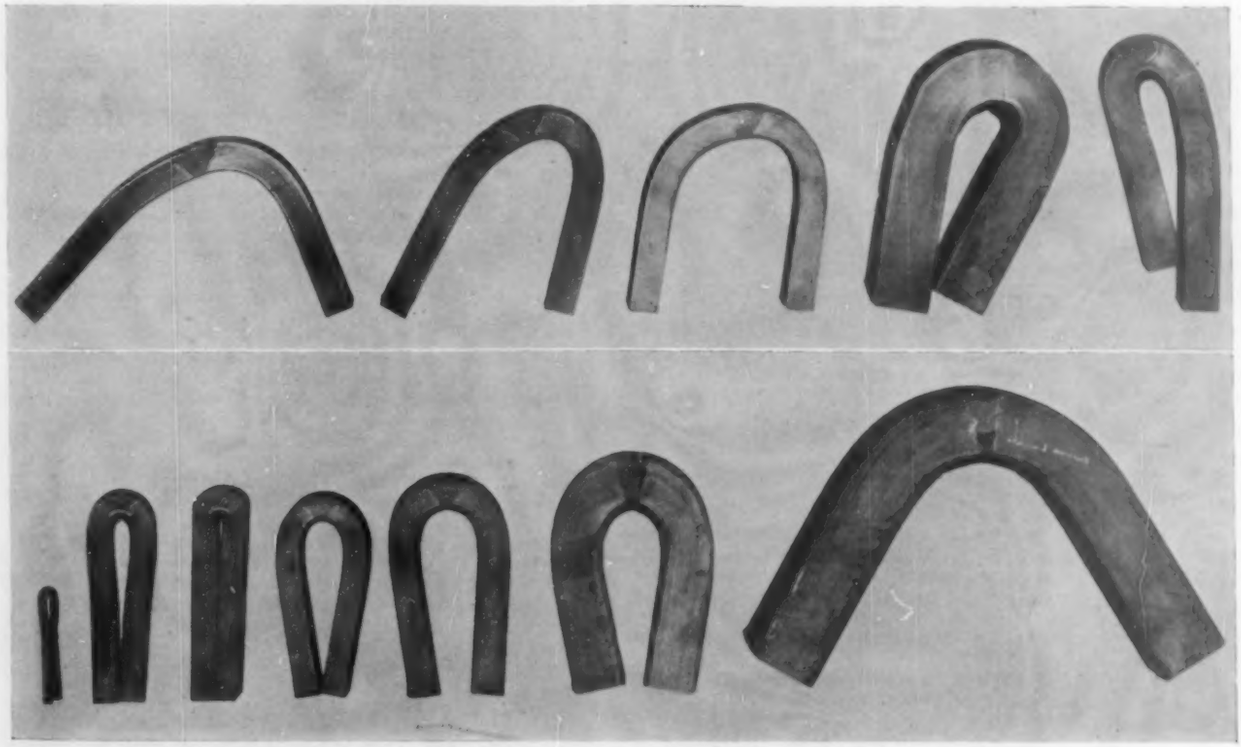


Fig. 5—Welded Specimens after Free-Bend Tests When Using Knurled Grip Fixtures. Maximum Bending Confined to Welded Section

as did the tendency of specimens to bend outside of the weld in the plate sections. The type of final face bends resulting from both the old method and the new preliminary bend fixtures are shown in Fig. 4.

With the thought in mind that it would be impossible to make satisfactory free-bend tests unless a method was developed for confining the bend to the weld metal, different types of fixtures were tried until one was found which gave satisfactory results and which confined the major bend to the weld metal. Such a fixture is shown in Fig. 2, and the method of using it in Fig. 3.

By making a knurled face on the fixtures the welded specimen was prevented from slipping, and it was not necessary to make any adjustments in the compression testing machine. A large number of welds have been tested in these fixtures, and several are shown in Fig. 5.

It is felt that this method of making free-bend tests on welded specimens very nearly approaches a true free bend as far as the weld metal is concerned. This weld section, after all, is the one in which designers and inspectors are interested, and by preventing the bend in the plate stock we are more nearly able to secure a true picture of what is occurring in the weld metal.

One other feature is the fact that, with the old method, the test specimen had a tendency to slip and fly out of the compression machine. The knurled fixtures prevent this and thereby add a safety feature to the method.

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Oxy-Gas Cutting. Flame Cutting and Profiling. Mech. World (Aug. 17, 1934), vol. 96, no. 2485, pp. 154–156; (Aug. 24), no. 2486, p. 170. Brief account of series of machines produced by Hancock & Co. with special details of new three-purpose straight-line and circle-cutting machine, known as "Circaline," for circle and straight cutting, and for moderate profiles when hand guided, particularly suitable for "taking to job" for either constructional or repair work.

Pipe Joints. Requirements for Welded Piping Joints, S. Crocker. Heating, Piping & Air Conditioning (July 1934), vol. 6, no. 7, pp. 298–300; (Aug.), no. 8, pp. 339–342. Code for pressure piping is explained and discussed.

Pipe Lines. Three-Flame Head Cuts Pipe Welding Cost One-Fourth. Oxy-Acetylene Tips (Aug. 1934), vol. 13, no. 8, pp. 173–178; see also Steel (Aug. 27, 1934), vol. 95, no. 9, pp. 30 and 32.

Power Plant Equipment. Electric Welding in Power-Plant Maintenance, J. W. Keck. Mech. Eng. (Oct. 1934), vol. 56, no. 10, pp. 609–612 and 630. Advance of use of electric welding in maintenance departments has largely resulted from improvement in welding technique and testing methods; various examples of applications and test results.

Railroad Maintenance of Way. Your Welding—Are You Getting Most from It? C. Wise. Ry. Eng. & Maintenace (Aug. 1934), vol. 30, no. 8, pp. 429–431. Methods of repairing switch points, frogs and rail ends that are used at North Western's Proviso Yard.

Shipbuilding. Welding Tests, J. L. Wilson. Mar. News (Aug. 1934), vol. 21, no. 3, pp. 65 and 77. Review of tests to show evolution of weld-test specimen forms as originally applied by American Bureau of Shipping and as related to amplification of such standards by tentative specifications issued by AMERICAN WELDING SOCIETY; for this purpose hull-construction welding is included.

Stainless Steel. Welding and Fabricating Stainless-Clad Steel. Am. Mach. (Aug. 1, 1934), vol. 78, no. 16, pp. 541–542. Reference book sheet data dealing with methods.

Structural Steel. Welding Regulations for Buildings, Bridge and Vehicles, O. Bondy. Ry. Engr. (June 1934), vol. 55, no. 6, pp. 176–178. Standard British and German rules for application of welding discussed and compared.

Testing. Non-Destructive Methods of Testing Welded Joints, C. E. Webb and L. H. Ford. Sheet Metal Industries (Sept. 1934), vol. 8, no. 89, pp. 544–545.

Testing. Welding and Weld Material, J. L. Adam. Sheet Metal Industries (Aug. 1934), vol. 8, no. 88, pp. 487–488.

Training Steamfitters to Weld, S. Plumley. Heating, Piping & Air Conditioning, Contractors Nat. Assn.-Official Bul. (Aug. 1934), vol. 41, no. 8, pp. 17–19. Program carried on at Washburne Vocational School in Chicago; 25 jobs constitute course of instruction.

Viaducts. Electric-Arc Welding Saves 40-Year-Old Viaduct. Ry. Eng. & Maintenance (Aug. 1934), vol. 30, no. 8, pp. 432–436. Manner in which arc process was employed in strengthening and repairing O-Street viaduct at Lincoln, Neb., by Chicago Burlington & Quincy, at relatively low cost.

(*Continued on page 33*)

WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

Fourteenth Fall Meeting of the American Welding Society

Without question the most successful Fall Meeting of the AMERICAN WELDING SOCIETY was held in New York on October 1st–5th, in connection with the National Metal Congress Exposition.

Twenty-five thousand people viewed the exposition at the Port of Authority building where the welding exhibits undoubtedly created the greatest attraction. Nineteen companies supplying apparatus and material for the welding industry had special exhibits. In addition, there were a number of important users of welding that showed the possibilities of fabrication by welding, particularly in the newer high-strength, light-weight and non-corrosive alloys.

These welding exhibits indicated the remarkable progress that has been made by the welding industry during the past few years. Speeds of welding considered impossible a few years ago are now everyday practices, with quality of weld equal and in many cases surpassing, the parent metal itself.

The technical sessions held at the Hotel New Yorker ranked equal in importance with the Exposition. Over 500 members of the Society and guests registered, attended the sessions and participated in the discussion. The papers covered a wide range of application. The outstanding feature of these sessions was the numerous reports of researches completed at university, governmental and company laboratories. There were actually more than a dozen of such papers. Some of them appeared in the September issue of the Journal, others were available in preprint form and still others will appear in subsequent issues of the Journal, so that all of the members of the Society will be able to take advantage of this latest information. There were many practical papers dealing with welding applications in residences, shipbuilding, railroad work, high-temperature pipe-lines, structural applications, the welding of light-weight and high-strength alloys, brazing, metal spraying, hard facing and welds subjected to low temperatures. One session was given over to a symposium on "Qualifying Operators of Welding Equipment and Expenses Incurred Therein."

These technical sessions were supplemented by two outstanding inspection trips.

On Friday morning, October 5th, a group of Welding Society members journeyed to Brooklyn to inspect the new and modern equipment of the Kings Brewery. Guided through the plant, the successive operations from the mixing of the ingredients to the brewing, cooling, aging and bottling of the amber fluid were described. Some of the interesting equipment included a completely welded 1000-barrel copper brewing kettle, welded steel mash and storage tanks and other miscellaneous equipment. At the conclusion of the tour through the plant, a light luncheon of beer and sandwiches was furnished by the officials of the brewery.

The other trip was held on Saturday morning to the Midtown Hudson Tunnel, which is a vehicular tunnel similar to the Holland Tunnel. It is being built by the Mason and Hanger Company, Inc., Geo. B. Montgomery, Supt., under the supervision of the Port of New York Authority, O. H. Ammann, Chief Engineer, through a loan of $37,500,000.00 granted by the Public Works Administration. The tunnel is shield driven, cast iron lined. The party was taken through the power house, through the machine shop, then across the railroad tracks, down a temporary stairway to a distance of 60 ft. to the bottom of the shaft. They saw the drillers, muckers actually at work, as well as the erection crew actually setting cast-iron segments of the tunnel lining, weighing about two tons apiece, and pulling them in place.

The outstanding social event was the stag dinner held on Thursday. Two hundred and fifty members and their guests participated in the very enjoyable dinner and variety show. There were no speeches and the expression "A good time was had by all" was literally true of this occasion.

The ladies were not neglected. On Monday there was a special luncheon and a tour of N. B. C. Studios. On Tuesday there was an inspection and tea on the S.S. *Aquitania*. On Wednesday a boat trip around Manhattan Island, and on Thursday a tour of Radio City, a visit to the Tower and to a broadcast. This was followed by a buffet supper at the Hotel New Yorker.

Miller Memorial Medal Award

The 1933 Miller Memorial Medal was awarded to Mr. J. C. Lincoln, Chairman of Board, Lincoln Electric Company, for outstanding meritorious achievement in the advancement of welding. The Medal and Certificate were presented by Mr. J. H. Deppeler, Chairman of the Board of Trustees, at the opening session of the Fall Meeting on October 1st. Members of the newly appointed Board are: F. T. Llewellyn, Chairman; W. H. Ludington and C. A. Adams.

In describing the work of Mr. Lincoln, Mr. Deppeler stated, that his electrical activities began in 1888 with the Brush Electric Company. A few years later he

joined the Elliott-Lincoln Electric Company, one of the pioneer manufacturers of motors.

In 1896 The Lincoln Electric Company was formed and under his proprietorship at first, presidency later, and about 1925 as Chairman of the Board, this Company built its first welder in 1907. This was for use in a steel foundry for heavy currents with the carbon electrode. The development of this type of apparatus was continuous during that period and has gone through the various types up to the present time with the high-voltage shielded-arc welding.

During the period beginning approximately in 1915, work was done on electrodes which resulted in 1929 in the shielded arc-welding electrode known as Fleetweld. During that period also, there were developed numerous other types of alloy rods under the names of Manganweld, Wearweld, Aluminweld, Lightweld, Ferrowweld, for various applications.

In 1917 a school was started in conjunction with the United States Government for the training of welders. This school has been in operation ever since and there have been trained in this activity probably in excess of five-thousand welding operators.

In about 1928 the first Lincoln arc-welding prize was offered which was followed up a few years later with the second one. This brought out a number of very large contributions to the art and has codified a number of the results which had never been published before.

The application of arc welding through The Lincoln Electric Company, under the leadership of J. C. Lincoln, has been applied in nearly all civilized countries of the world to thousands of different activi-

ties all the way from erecting office buildings to the welding of automobile mufflers.

Another activity of the Company under this same leadership is the development of the Electronic Tornado which is the only commercially successful automatic welding device using the carbon electrode. This equipment is used very largely in competitive work and is undoubtedly in a class by itself for this type of operation.

The company also, under the same leadership, has done a tremendous amount of engineering work for the application of arc welding to many devices.

International Acetylene Association Meeting

The convention will be held at the William Penn Hotel, Pittsburgh, November 14th, 15th and 16th. Members of the society are invited to attend.

The program includes presentation of the Oxyacetylene Committee Report, by G. O. Carter; a session on Oxyacetylene Cutting with Particular Reference to Steel Mill Applications; an industrial drama in four acts, entitled "Profits of Progress"; series of papers dealing with the Metallurgical Aspects of the Oxyacetylene Process; and a session each on Pipe Welding and Testing, Transportation, and Education and Safety in Welding.

United States Civil Service Examination

The United States Civil Service Commission has announced an open competitive examination as follows:

Metallurgist

Applications for the position of metallurgist in the Ordnance Bureau, War Department, with headquarters at Rock Island, Ill., must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than November 8, 1934.

The entrance salary is $3800 a year, subject to a deduction of not to exceed 5 per cent during the fiscal year ending June 30, 1935, as a measure of economy, and to a deduction of 3½ per cent toward a retirement annuity.

Applicants must show that subsequent to college graduation they have had, except for the substitution mentioned below, at least five years of progressive professional experience in important and responsible physical metallurgical work which must have included the supervision of and responsibility for the work of others. Such experience must have included research work in the analysis and testing of metals, the heat treatment of ferrous and nonferrous metals and alloys and their castings, the preparation of specifications for fabricated metallurgical materials, and contact work with technical heads of other important sections of large manufacturing establishments.

Postgraduate work in physical metallurgy successfully completed in a college or university of recognized standing may be substituted year for year for the prescribed experience up to a maximum of three years.

Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post office or customhouse in any city which has a post office of the first or the second class, or from the United States Civil Service Commission Washington, D. C.

Membership Drive

The Membership Committee is about to launch a new drive. The success of the drive last year was made possible only by the loyal cooperation of a small group of the members of the Society who assisted in furnishing lists of prospective members and in cooperating in other ways. This year it is the desire of the Membership Committee to secure the cooperation of a larger number of its members.

The Society is performing a really worth-while task and has assisted materially in the development of the welding industry through the preparation of suitable codes, standards and specifications; in the conduct of research work; in its various publications and its National and Section meetings. The Membership Committee would particularly appreciate the names of prospective members at this time.

SECTION ACTIVITIES

BOSTON

The American Society of Metals, Boston Chapter, has extended an invitation to the Boston Section to attend their meeting on November 2nd at the Fore River Plant of the Bethlehem Shipbuilding Corporation.

The afternoon will be devoted to shop inspection trips at the Fore River Plant, starting at 2:00 P.M. and occupying until 5:30. Dinner will be served between 6:00 and 6:30 to those making reservations, at a cost of about $1.00 per person.

Mr. John E. Burkhardt, Chief Engineer of the Fore River Plant, will tell, as a coffee talk, some of his experiences in shipbuilding.

Professor Comfort Adams, Harvard University, and a member of our own Section, will be the main speaker of the evening.

DETROIT

A joint meeting with the American Society of Mechanical Engineers local section was held on October 16th at the Fort Shelby Hotel. Mr. Edward G. Budd, President, and Mr. Joseph W. Winlock, Metallurgist of the Edward G. Budd Manufacturing Company, presented a lecture on "Shot Welding of Stainless Steel as Applied to the Burlington Zephyr."

NEW YORK

The opening session of the New York Section was held on October 23rd in Engineering Societies Building and was devoted to a Symposium and Exhibition on the Welding of Copper & Brass. New developments in the joining of copper alloys by both the oxyacetylene and electric welding processes were described. The two formal papers of the evening were: "High Voltage Carbon Arc Welding of Copper and Its Alloys," by C. E. Swift, American Brass Company; "Some Recent Developments in Silver Solders," by Arthur N. Kugler, Air Reduction Sales Company. This occasion was a social one as well as technical. Refreshments were served.

PHILADELPHIA

The regular monthly meeting of the Philadelphia Section was held on October 15th in the Auditorium of the Engineers' Club. Mr. G. A. Hughes, Chief Electrical Engineer of the Truscon Steel Company, spoke on "Resistance Welding, Strength and Application." Mr. C. H. Heitman, Hi-Tensile Division, Edw. G. Budd Manufacturing Company, spoke on "Shot Welding."

The November meeting will be held on the 19th. Dr. D. S. Jacobus, Advisory Engineer of the Babcock & Wilcox Company and President of the AMERICAN WELDING SOCIETY, will address the meeting on "The Historical Developments of Fusion Welded Steam Boiler Drums and Pressure Vessels."

PITTSBURGH

The first Fall Meeting of the Pittsburgh Section was held on Wednesday night, October 17th in the Fort Pitt Hotel. This meeting was devoted to the installation of the new officers for the coming season, a report on the 1934 Fall Meeting & Exposition in New York by W. W. Reddie, National Representative, and a showing of slides collected by Mr. James Lee, Managing Editor of *Chemical & Metallurgical Engineering*, depicting applications and developments in welding. Mr. Walter G. Myers of the Linde Air Products Company discussed the slides as they were shown.

A joint meeting with the Engineers' Society of Western Pennsylvania will be held on October 23rd in the William Penn Hotel. Mr. A. M. Candy of the Westinghouse Electric & Mfg. Company will speak on "Welding as Applied to the Steel Industry."

PORTLAND

A very interesting meeting of the Section was held on September 24th at which Dr. Jacobus, President of the Society, presented an address on the Historical Developments of the Application of Welding in the Fabrication of Pressure Vessels and also terms and possibilities for the future. This address was illustrated by

lantern slides and included, also, a discussion of welding at the Boulder Dam. The meeting was arranged as a joint meeting with the A. S. M. E. About seventy people were present. As a result of this visit, it is expected that renewed interest will be aroused in the Portland Section.

SAN FRANCISCO

The October meeting of the San Francisco Section was held on October 19th at the Athens Athletic Club, Oakland, Calif. Mr. C. B. Leahy, Supervisor of the Applied Engineering Department of the Air Reduction Sales Company presented a paper on "Recent Developments in Oxyacetylene Machine Cutting," which was illustrated by lantern slides.

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A-218. Electric welder operator. Experienced in use of Lincoln and General Electric welding machines, use of stable-arc, fleetweld, ferroweld, light weld, copper, aluminum and stainless steel rods. Attended Lincoln Welding School. Has Civil Engineer degree. References.

A-219. All-around welder with twenty years' experience desires position.

Current Welding Literature

(*Continued from page 30*)

Welds. Studies on Metallurgy of Arc Deposited Weld Metal, S. L. Hoyt. Am. Soc. Metals—Advance Paper No 20, mtg. Oct. 1–5, 1934, 24 pp. Chemical analysis, mechanical properties, and structure of weld as deposited with cellulose type of weld rod; comparison with metal deposited with bare-wire electrode; occurrence of oxygen as FeO, MnO, SiO_2 and Al_2O_3 given for different weld-metal types as determined by "fractional oxygen" method of analysis; significance of foreign inclusions.

BOOKS

Tractograph booklet. Issued by Air Reduction Sales Company. Sets forth how machine is operated and what it can accomplish. Copiously illustrated. Copies may be obtained from Air Reduction Sales Co., New York, N. Y.

"Riveting and Arc Welding in Ship Construction," by Commander H. E. Rossell. Published by Simmons-Boardman Publishing Co., New York, N. Y. Price $2.25. Since the hull of a ship is made of numerous plates and shapes the methods available for joining these parts dictate to a large degree the type of construction which must be employed. The principles underlying the design of joints in structures, therefore, are of fundamental importance to the naval architect.

Acting upon the above premise, the author has gathered together from many scattered sources information on this subject and has attempted to present it in such a way that it will be of use not only to students of naval architecture at technological schools but also to ship draftsmen and structural engineers. In so doing he has discussed in considerable detail both riveted and arc-welded joints, viewed from the practical as well as the theoretical standpoint.

"The Chemical Formulary," published by The Chemical Formulary Co., 175 Fifth Avenue, New York, N. Y. The book contains the condensed collection of valuable, timely, practical formulae for making thousands of products in all fields of industry. Over forty industrial chemists, professors and technicians in many branches of industry have cooperated to make this book available. Mr. H. Bennett is the Editor-in-Chief. 600 pages. Price, $6.00.

"Practical Everyday Chemistry." An authoritative book which presents in a practical way information as to how the things used in daily life are made and their compositions. Published by the Chemical Publishing Company, 1450 Broadway, New York, N. Y. Edited by H. Bennett. Price, $2.00.

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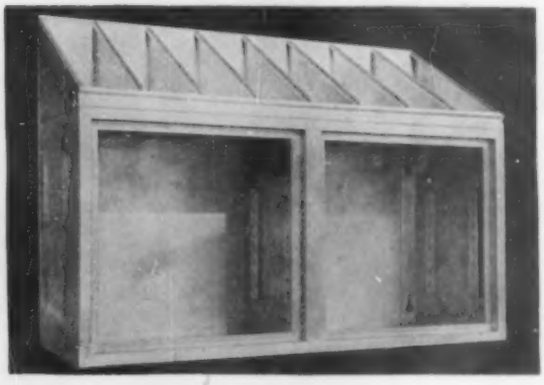

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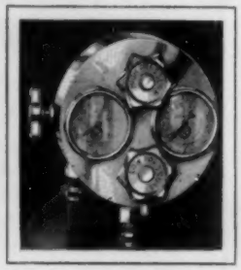

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REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912

OF JOURNAL OF AMERICAN WELDING SOCIETY, published monthly at Easton, Pa., for October 1, 1933.

State of New York } ss.
County of New York }

Before me, a Notary Public in and for the State and County aforesaid, personally appeared William Spraragen, who, having been duly sworn according to law, deposes and says that he is the Editor of the Journal of the American Welding Society and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Name of — Post Office Address

Publisher, American Welding Society, 33 W. 39th St., New York, N. Y.
Editor, William Spraragen, 33 W. 39th St., New York, N. Y.
Managing Editor, William Spraragen, 33 W. 39th St., New York, N. Y.
Business Manager, M. M. Kelly, 33 W. 39th St., New York, N. Y.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

American Welding Society, 33 W. 39th St., New York, N. Y.
D. S. Jacobus, President, % Babcock & Wilcox Co., 85 Liberty St., New York, N. Y.
M. M. Kelly, Secretary, 33 W. 39th St., New York, N. Y.
C. A. McCune, Treasurer, 25 West 43rd St., New York City.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)
None.

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W. SPRARAGEN, Editor.

Sworn to and subscribed before me this 13th day of September, 1934.

(Seal) MARY T. HICKEY
Notary Public, New York County, New York County Clerk's No. 138.

New York County Register's No. 6-H-316
(My commission expires March 30, 1936)